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17/24 December 2022

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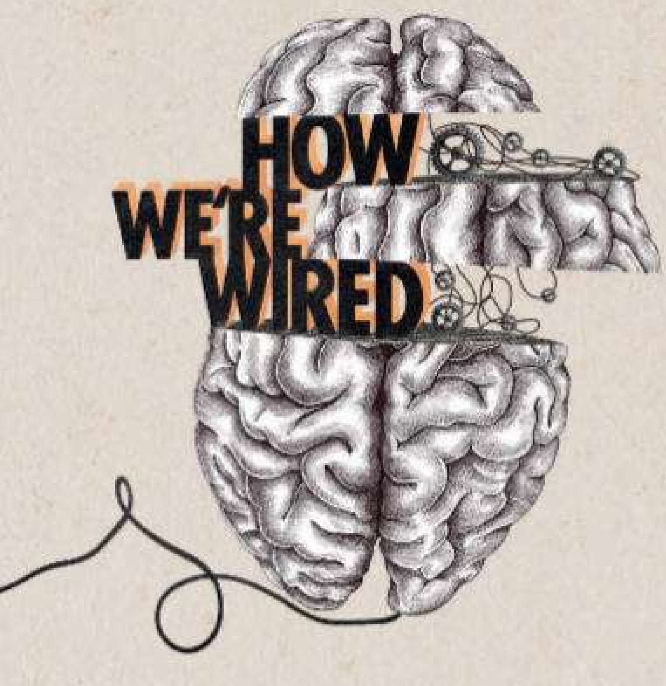

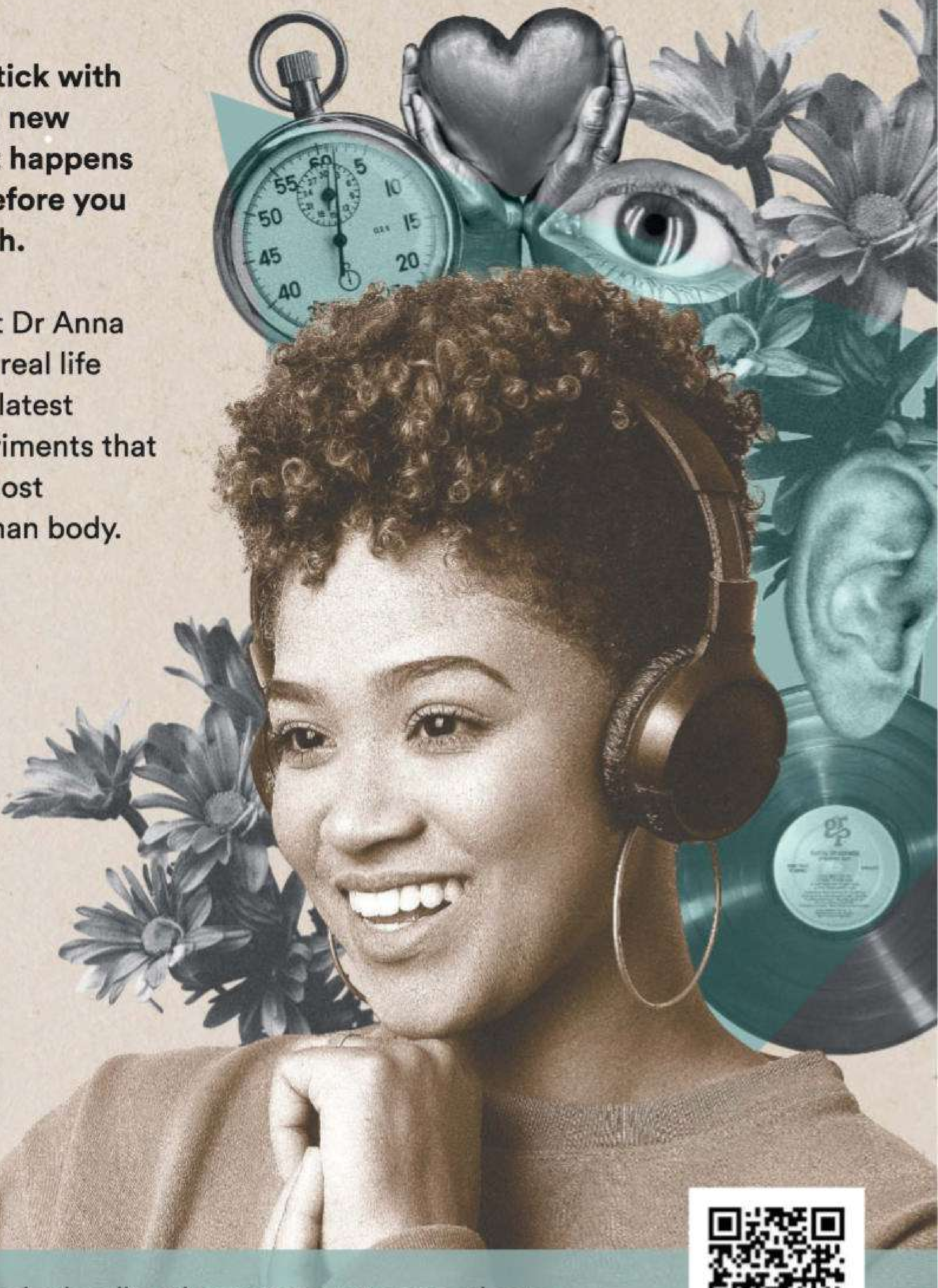

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This week's issue

Christmas & New Year special

Vol 256 No 3417/18
Cover image: Rob Snow

Welcome, dear readers, to this holiday edition of *New Scientist*.

This year we have for you the search for a long-lost land, adventures close to absolute zero, fiendish puzzles, an exclusive short story from a top sci-fi writer and (with apologies to more sensitive readers) some pictures of animal poo for you to identify. We do hope you enjoy!

On behalf of all of the team at *New Scientist*, may I also take this opportunity to wish you a wonderful holiday season and a happy, healthy and, of course, scientifically robust 2023.

Emily Wilson
New Scientist editor-in-chief

News

7 To the moon and back
Orion capsule splashes down after 26-day journey

8 CRISPR treatment
Girl with leukaemia receives gene-editing therapy

9 Could we spot a warp drive?
Gravitational wave detectors might pick up spaceship

Review of the year

19 Tonga eruption
The most explosive volcano this century

21 Global family tree
Study shows the relationships of all humanity

22 Fallout from COP27
The next climate battle

23 Rise of xenotransplants
First person receives pig heart

26 James Webb's cosmic glory
Space telescope's amazing images of the universe

TATYANAMISHCHENKO/GETTY IMAGES

53 Deep and crisp and even The beautiful – but threatened – subnivium

Features

50 The hunt for the mysterious land of Punt
We finally found the ancient Egyptians' land of luxuries

53 Hidden glory of the subnivium
The life thriving under the snow

55 Vegan fine dining
Cordon bleu cooking without the side order of climate guilt

58 How reindeer see in the dark
It is all down to their incredible colour-changing eyes

60 Board games go quantum
How to beat your family using quantum pseudotelepathy

62 What a wreck!
The story of a special shipwreck

64 Our messages so far to deep space
And what any aliens that have heard them will think of us

66 Curious survival of the cassette tape
Why big tech stores your photos in a surprisingly retro fashion

Features

RUBY FRESSON

68 Bizarre brassicas Where sprouts and their ilk really come from

Features cont.

68 The mother of all sprouts
Searching for the common ancestor of the sprout and its sister vegetables

70 Be kind to yourself
Why self-compassion is the key to cultivating generosity

72 Outrageously lazy animals
Meet the "lazy Geoffs" and discover how they get away with idleness

74 Exploring absolute zero
How we reached the coldest possible temperature – and what's down there

77 Chris Packham's poo picture puzzle
Hold your nose and engage your brain

Views

31 The columnists
New Scientist's columnists give their unique take on the year

34 Letters
Details of first language may be lost forever

36 Culture short story
An exclusive science-fiction story by Arkady Martine

46 Aperture
A storm captured in full fury and a frozen Niagara Falls

Festive fun

43 Cosmic challenge
Can you crack our interlinked space-themed puzzles?

Backpages

81 Citizen science
Join the Christmas Bird Count

82 Puzzles & bumper crossword
Try our cryptic crossword and brainteasers

84 Quiz of the year
Can you remember all the biggest science news of 2022?

86 Puzzle and quiz answers
Find out how well you did

88 Feedback
Seasonal swings and white noise

88 Twisteddoodles for *New Scientist*
Picturing the lighter side of life

Elsewhere on New Scientist

Virtual event

Wonders of the Arctic: Science on top of the world

The Arctic is a harsh yet beautiful region that has fascinated scientists for centuries. Join *New Scientist*'s Rowan Hooper for this free talk on the region's wildlife and how humans could refreeze ice in the Arctic circle. We will also hear from glaciologist Ulyana Horodyskyj Pena, who will tell us about the life of a scientist in an extreme environment. On 12 January 2023 at 8pm GMT/3pm EST and later on demand.

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Podcasts

Weekly

Podcast host Rowan Hooper speaks to Shakespearean scholar Randall Martin about the surprising influence that climate change and a 16th-century energy crisis had on Shakespeare's plays. Plus, the team hear the latest from the COP15 biodiversity summit. Also over the holiday period: a special behind-the-scenes podcast looking at our favourite features of the year.

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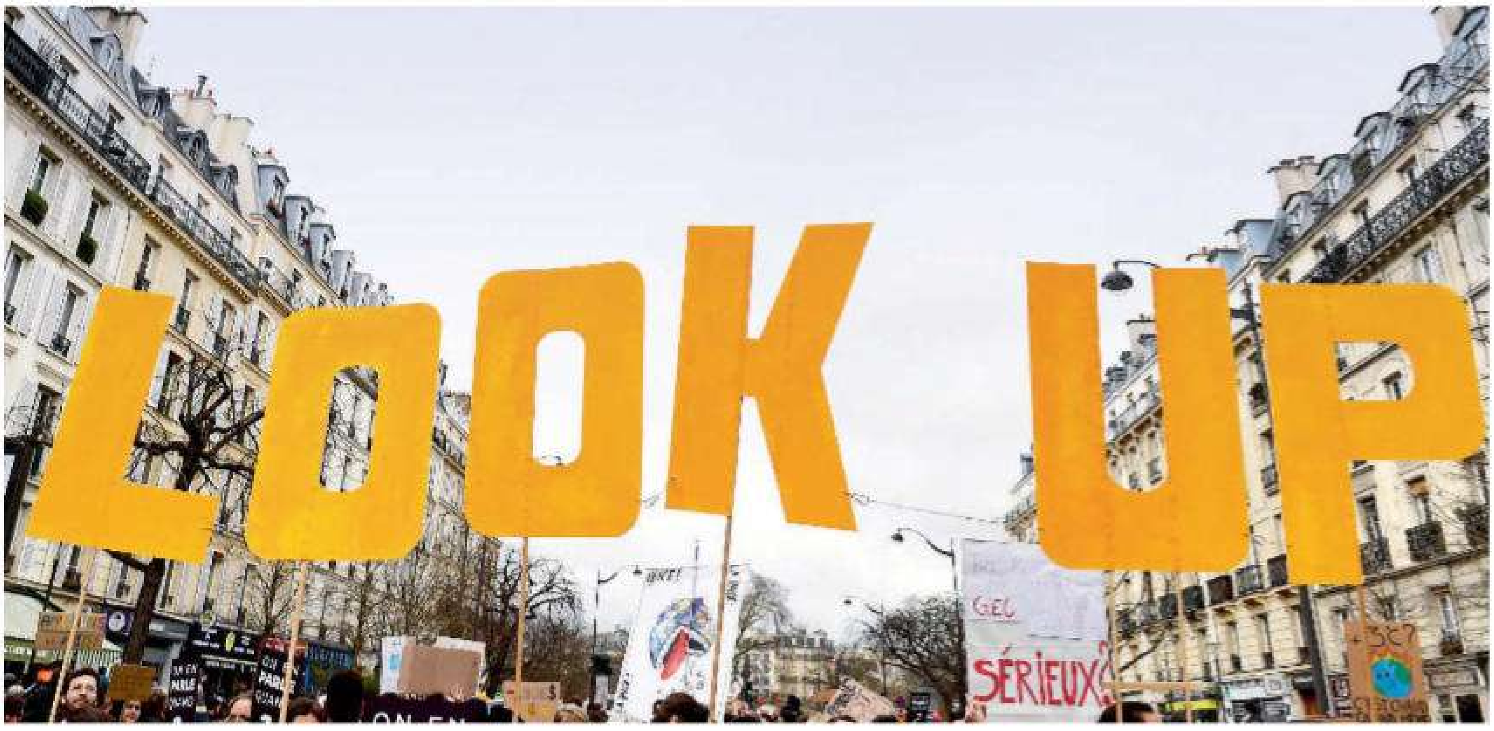
Another rollercoaster year

War, high prices and extreme weather came with a green energy shift and space joy



ALAIN JOCARD/AFP VIA GETTY IMAGES

WHAT a year. At the start of 2022, many were hoping for a return to normality as vaccines allowed countries to end covid-19 measures (see page 24). Instead, Russia invaded Ukraine, triggering or exacerbating many other global crises in addition to the terrible things happening in Ukraine itself.

Russia attempted to blackmail Europe by withholding gas, sending energy prices soaring. It also prevented the export of grain and sunflower oil from Ukraine's ports, sharply hiking food prices. Along with the supply chain disruptions resulting from the pandemic – and from Brexit in the UK – this led to the cost-of-living crisis that is affecting people all around the world, making it hard for many to afford food and heating.

As leaders struggled to deal with this interlinked polycrisis, the headline-grabbing promises made in 2021 at the COP26 climate summit in the UK were quickly forgotten. Instead of the agreed phasing down of coal, there was a coal comeback as countries scrambled to find alternatives to Russian oil and gas.

Yet this year, the reasons why it is so vital to limit global warming became more obvious than ever. There were many record-breaking droughts and heatwaves across the world (page 28), with China enduring by far the most extreme heatwave ever recorded, the UK hitting 40°C (104°F) for the first time and even Antarctica having extreme heat, relatively speaking (page 25).

There were also major storms and flooding. In Pakistan, floods killed 1700, with the damage estimated at a staggering $30 billion. Demands for the high-income countries responsible for most global warming to pay compensation to nations like Pakistan hit by climate-related disasters finally resulted in a fund being established at the COP27 climate summit in Egypt last month, but the donations so far are minuscule.

There was little progress on other issues either (page 22). On the contrary, it is becoming ever clearer that the world will pass the 1.5°C "limit" sometime in the 2030s – and that the consequences could be even more severe than currently forecast.

Meanwhile, as the global population passed the 8 billion mark, the destruction of nature continued apace, with vital rainforests still being cut down across the tropics and coral reefs bleaching once again. Yet instead of strengthening protections for nature, countries such as the UK tried to roll them back.

Then, there is the continuing threat from infectious diseases. This year, mpox (formerly called monkeypox) spread beyond Africa and infected at least 80,000 people across the world, killing dozens. It could have been much worse. The virus variant responsible is seldom lethal and mostly spreads via sex. What's more, smallpox vaccines and treatments are effective against it. But this outbreak could have been avoided if an mpox vaccine had been developed and rolled out in the countries where the virus is endemic. Much more needs to be done to prevent viruses like this jumping to people – next time, the world might not be so lucky.

Indeed, given the extraordinary happenings of the past few years, it is hard not to wonder what fresh catastrophes 2023 might bring. Yet there are many reasons for a certain optimism, too.

For starters, it looks increasingly likely that, with the help of many other countries, Ukraine will take back all its territory. This victory could lead to Vladimir Putin's exit and seismic shifts in Russia. While Russians could pay a huge price and such a change poses a risk in a former superpower with lots of nuclear weapons, it could lead to some positive outcomes as well.

A Russian defeat would help deter a Chinese invasion of Taiwan, which would also have many serious global impacts on top of the human cost of conflict. For one thing, Taiwan makes nearly all the advanced chips in our phones and computers. And China produces 70 per cent of all solar panels, so such a war could derail the renewable energy revolution.

A diminished Russia may reduce its often malign attempts to influence the West, which include resisting climate action and promoting scare stories about vaccines and genetically modified crops. Some in Ukraine are calling for the denuclearisation of Russia if it is defeated, which, while unlikely, would make the world a safer place.

Whatever comes to pass, Russia has, ironically, already done more to promote renewable energy than climate activists ever could. Wind and solar have always been the green option. In recent years, they have become the cheap option and now they are being seen as the most secure option, too. That is a combination that fossil fuels can't beat.

Earlier this month, the International Energy Agency made the biggest ever upwards revision, of more than 30 per cent, to its forecast for renewable energy growth. The agency attributes this to security concerns caused by Russia's invasion of Ukraine.

Another major boost for climate action will come from the Inflation Reduction Act, a landmark piece of climate legislation passed in the US earlier this year. It provides around $370 billion in funding for reducing emissions.

> **"Russia has, ironically, done more to promote renewable energy than climate activists ever could"**

In Brazil, meanwhile, Luiz Inácio Lula da Silva has promised to reverse the destruction of the Amazon rainforest after he becomes president on 1 January.

This year, the James Webb Space Telescope has brought us many stunning images, from the most distant galaxies ever observed to direct images of exoplanets much closer to home (page 26). The telescope even spotted chemical reactions taking place in the atmosphere of one exoplanet. It is our best hope for spotting signs of life on other worlds.

But for now, Earth is the only planet known to be home to life. We need to redouble our efforts to protect that life. The 1.5°C goal might now be beyond us, but we must fight harder than ever for 1.6°C, and 1.7°C, and every fraction of a degree after that. ▮

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Deepfake detector
AI learns to spot imitations of world leaders p10

Oldest DNA
Genetic analysis reveals Greenland's ancient fauna p12

Going nowhere
Why you may never get your own self-driving car p13

Asteroid survivors
Mammals were primed to take over the world p14

Unhealthy habits
Smoking and drinking linked to genetic variants p16

NASA/KIM SHIFLETT

Space exploration

NASA's moon craft splashes down

The successful landing of the uncrewed Orion capsule sets up return trips that could see astronauts exploring the lunar surface once more, says **Leah Crane**

STEP one of NASA's return to the moon is complete. On 11 December, the uncrewed Orion capsule splashed down in the Pacific Ocean off the coast of California, completing its 26-day journey to the moon and back as part of the Artemis I mission.

The return was unlike those of other lunar spacecraft. It began as it hurtled into the atmosphere, with its heat shield reaching temperatures of around 2760°C.

But instead of continuing to plunge towards the sea, the capsule performed what engineers call a skip entry because of its similarity to a stone skipped across a pond. Once it reached an altitude of about 61 kilometres, it flipped upside down to quickly change its centre of gravity, popping it back upwards by about 30 kilometres, nearly all the way back into space, before making its final descent.

There are three reasons for this manoeuvre: it allowed operators to target the landing site more precisely; it lowered the strain on the heat shield; and it reduced the maximum g-forces on the ship by more than 40 per cent, which will make future Orion landings easier and safer for astronauts.

> "The splashdown of the Orion capsule was the ultimate test before we put astronauts on board"

Everything appeared to go well with the splashdown, which NASA administrator Bill Nelson called "the ultimate test before we put astronauts on board". The next step is for spacecraft engineers at NASA to go through the data from the landing to make sure the capsule – especially the heat shield – held up well enough to be confident that astronauts on the Artemis II mission will be as safe as possible.

That roughly 10-day mission, scheduled for 2024, will carry four astronauts around the moon and back, to perform a final test of the capsule's life support systems before Artemis III. This flagship mission, planned for 2025, will carry two astronauts to the moon's surface for just over six days, including the first woman ever to walk on the moon, while two others remain in lunar orbit. In total, that trip is intended to last about 30 days.

If it goes ahead, Artemis III will be the first time anyone has set foot on the moon since Apollo 17 in 1972. It will set the scene for NASA's intensive plans for lunar exploration, which include a space station orbiting the moon along with a permanent lunar base. ▮

The Orion capsule being recovered after its ocean landing

Health

CRISPR has promise for leukaemia

An experimental technique led to no detectable cancer cells in one girl with the condition

Michael Le Page

GREAT ORMOND STREET HOSPITAL FOR CHILDREN

Alyssa being treated at Great Ormond Street Hospital, London, in May

A TEENAGER with aggressive leukaemia now has no detectable cancer cells after becoming the first person to receive a new kind of CRISPR gene-editing treatment, called base editing. It won't be clear for some years whether she will remain free of leukaemia.

Alyssa (pictured), who is 13 years old, hadn't responded to other treatments. As part of a trial, she received a dose of donated immune cells from a donor that had been modified to attack the cancer. Twenty-eight days later, tests revealed she was in remission, according to results presented at the annual American Society of Haematology meeting in New Orleans, Louisiana, last week.

Leukaemia is usually treated by chemotherapy and a bone marrow transplant. If this fails, doctors can try so-called CAR-T therapy.

This involves adding a gene to a type of immune cell known as a T-cell that causes it to destroy cancerous cells. The modified cells are known as CAR-T cells.

> "This treatment is particularly promising, not just for cancer, but also for genetic disorders"

Initially, all CAR-T treatments involved removing a person's own T-cells, modifying them and replacing them in that individual. If T-cells from another person are used, they attack every cell in the recipient's body. This personalised approach is extremely expensive and often it isn't possible to obtain enough T-cells to create CAR-T cells when an individual is very ill.

To overcome these drawbacks, doctors have been gene editing T-cells so that those from a single donor can be used to treat many people. This method is approved in the UK for people whose leukaemia involves B-cells, another immune cell. Alyssa's leukaemia was caused by T-cells and if CAR-T cells are modified to attack other T-cells, they kill each other.

Robert Chiesa at Great Ormond Street Hospital in London and his colleagues therefore made an additional change to the CAR-T cells by knocking out the gene for the receptor that identifies them as T-cells. This requires four gene edits, leading to another problem.

Conventional gene editing involves cutting DNA strands and relying on a cell's repair machinery to rejoin the ends. When lots of cuts are made at once, cells sometimes die. Even if they survive, the wrong ends can be put back together, leading to major mutations that can potentially make the cells cancerous. The more gene edits that are made, the more likely this is to occur.

The team therefore used a modified form of the CRISPR gene-editing protein that doesn't cut DNA, but changes one DNA letter to another, a technique known as base editing. Alyssa is the first person ever to be treated with base-edited CAR-T cells.

"Base editing is particularly promising, not just in this case, but for genetic disorders," says Robin Lovell-Badge at the Francis Crick Institute in London. Many other treatments involving CRISPR base editing are being developed, he says. ▮

Conservation

Lab-grown stem cells may help to save white rhino

CELLS with the potential to form sperm and eggs have been derived from northern white rhino skin, raising hopes that lab-grown embryos could help efforts to save the animals from extinction.

The only two remaining northern white rhinos (*Ceratotherium simum cottoni*) are females – Najin and her daughter Fatu at the Ol Pejeta Conservancy, a reserve in Kenya. Researchers are already working on a plan to save this subspecies by using sperm from deceased male rhinos to fertilise egg cells collected from Najin and Fatu. This has so far produced 22 embryos that have been frozen for future implantation in southern white rhinos (*Ceratotherium simum simum*), a closely related subspecies of which about 20,000 remain in southern Africa.

THOMAS MUKOYA/REUTERS/ALAMY

Fatu and Najin, the last two northern white rhinos

Another possible way to produce embryos would be to turn skin cells from northern white rhinos into stem cells, which have the ability to turn into various types of specialist cell. These could then be coaxed to form eggs and sperm – an approach that has worked in mice.

To test this method for northern white rhinos, Katsuhiko Hayashi at Osaka University in Japan and his colleagues bathed northern white rhino skin cells, taken from a female that died in 2015, in a cocktail of chemicals that turned them into stem cells.

The team then found the best mixture of growth factors and chemicals to make these stem cells turn into the precursors of sperm and eggs, called primordial germ cell-like cells (*Science Advances*, doi.org/grghgx).

"This was a lot of hard work and it will be very beneficial to the field," says Jeanne Loring at the Scripps Research Institute in California. But further work is needed to see if such egg and sperm cells result in fertilised embryos, she says. ▮

Carissa Wong

Technology

Crawling robots will survey ageing US nuclear missile silos

David Hambling

ROBOTS will be employed to automate the maintenance of nuclear missile silos in the US.

There are some 400 steel and concrete silos housing Minuteman III intercontinental missiles in the US. Constructed in the early 1960s, each silo is 30 metres deep and 5 metres across, with a missile inside.

The missiles and silos are years beyond their planned service lives, but the US Air Force's Minuteman IIIs act as a nuclear deterrent, and they will continue in this role until they are replaced by Sentinel missiles, which is planned in the next decade.

To check whether the facilities are still fit for purpose, silos have previously been inspected by subjective, manual methods, says a spokesperson for Gecko Robotics, which has won a $1.5 million contract to use robots for the task. Yet it can be hard for a person to check the sheer, curved internal wall of a silo when much of the space is occupied by a missile, and dropping a tool could conceivably lead to damage or explosions.

Gecko Robotics has pioneered robots to inspect storage tanks and ship's hulls. Its TOKA series robots can climb walls, crawl at up to 20 metres a minute and are loaded with sensors and cameras.

The readings the robots take enable the creation of a high-resolution 3D model of the area. "We're able to provide the Air Force with a digital twin of the facilities to help them identify problem areas," says the spokesperson.

Gecko Robotics will equip the robots with echo impact sounders to assess reinforced concrete. These are essentially an automated version of a surveyor tapping with a hammer and listening for a change in note, says Phil Purnell at the University of Leeds, UK.

The surveys should reveal whether the silos need repairs or should be taken out of service. ▮

Space

Gravitational wave detectors could spot alien warp drives

Leah Crane

WE MAY be able to spot enormous alien spacecraft by the gravitational waves they would create. Gravitational waves are ripples in space-time formed when a massive object moves around, so if there are any extraterrestrials driving gigantic spacecraft around our galaxy, the Laser Interferometer Gravitational-Wave Observatory (LIGO) in the US could potentially detect them.

Gianni Martire at Applied Physics, a research institute in New York, and his colleagues calculated how large such a craft would have to be, and how fast it would have to move, to create a gravitational wave big enough for LIGO to spot. They found that the craft would have to be about the mass of Jupiter, travelling at about one-tenth the speed of light – that is nearly 30,000 kilometres per second, faster than any star astronomers have discovered.

They found that LIGO could spot such a craft if it travelled within about 326,000 light years of Earth, and more sensitive planned gravitational wave detectors could extend that distance even further (arXiv, doi.org/jp3n).

***Star Trek's* Enterprise uses a warp drive**

PARAMOUNT+

"With trillions of stars out there, you're telling me that one doesn't have aliens that haven't done this? Just one? I think the odds are in our favour," says Martire. "I wouldn't want to be on the team figuring out how to build a Jupiter-sized spacecraft, but the odds aren't zero."

30,000

Speed in km/s an alien craft would have to travel to spot it

This could also work for crafts using warp drives, theoretical engines that move by creating their own wrinkles in space-time. "There's no way in hell we could detect a craft so far away in other ways, even if it's as big as Jupiter," says Martire. "The LIGO folks and the SETI [Search for Extraterrestrial Intelligence] folks should be best friends."

But even though it is clear that extraordinarily massive spacecraft and warp drives should create gravitational waves, other researchers are sceptical that we will ever be able to actually detect them.

"This is well and fine in principle, it's just that I am surprised they find the result to be in the sensitivity range of LIGO," says Sabine Hossenfelder at the Munich Center for Mathematical Philosophy in Germany. "If the spacecraft was actually Jupiter, which is pretty close, maybe we'd actually be able to measure it, but if it was much further away, probably not."

Even if we were to detect gravitational waves from a huge, fast-moving object, it would be hard to discern whether it was an alien spacecraft or a natural phenomenon. It could be easier for warp drives because of the unique way they are expected to affect the gravitational field around them. "How do you know the difference between a comet and the starship Enterprise? You can tell between a rock and a warp drive the same way you can tell whether a jet ski went past or a boat," says Martire. "They both create waves, but they have a particular signature in their wake."

There is no downside in checking for an outlandishly enormous spacecraft in LIGO data, says Hossenfelder. "It's there, it's collected already and freely available, I don't see why not," she says. "I'm just not that excited about the idea that they'll actually find anything."

If they do, even if it isn't an alien spacecraft but simply a huge object moving far faster than we expect anything that big to go, it would be an important find. "Even if it's not aliens, it'd be something new," says Martire. "It would be exciting no matter what it is." ▮

For more aliens, see page 64

Technology

Deepfake detector could protect world leaders

Jeremy Hsu

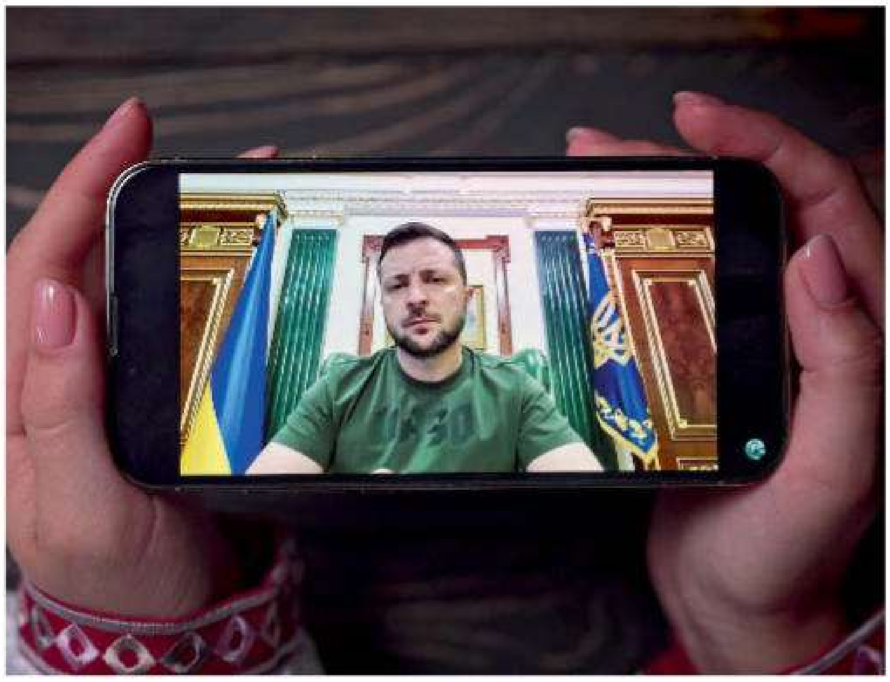
A DEEPFAKE detector can spot fake videos of Ukraine's president Volodymyr Zelenskyy. This system could not only protect Zelenskyy, who was the target of a deepfake attempt during the early months of the Russian invasion of Ukraine, but also be trained to flag fakes of other world leaders.

"We don't have to distinguish you from a billion people – we just have to distinguish you from [the deepfake made by] whoever is trying to imitate you," says Hany Farid at the University of California, Berkeley. He and Matyáš Boháček at Johannes Kepler Gymnasium in the Czech Republic developed detection capabilities for faces, voices, hand gestures and upper body movements.

They trained a computer model on more than 8 hours of video of Zelenskyy that had previously been posted publicly.

The detection system then scrutinises 10-second clips from a single video, analysing up to 780 behavioural features. If it flags multiple clips from the same video as fake, human analysts take a closer look.

Based on real videos the system is trained on, it can detect when something doesn't follow a person's usual habits. "[It] can say, 'Ah, what we observed is that with President Zelenskyy, when he lifts his left hand, his right eyebrow goes up, and we are not seeing that'," says Farid. "We always imagine there's going to be humans in the loop, whether those are reporters or analysts at the National Security Agency, who have to be able to look at this being like, 'Why does it think it's fake?'"


KRISTINA KOKHANOVA/ALAMY

Video of a real speech by Ukrainian president Volodymyr Zelenskyy

The holistic head-and-upper-body analysis is uniquely suited to spotting manipulated videos and could complement commercial deepfake detectors that mostly focus on spotting less intuitive patterns involving pixels and other image features, says Siwei Lyu at the University at Buffalo in New York.

"Up to this point, we have not seen a single example of deepfake generation algorithms that can create realistic human hands and demonstrate the flexibility and gestures of a real human being," says Lyu. That gives the detector an advantage in catching deepfakes that fail to convincingly capture the connections between facial expressions and other body movements – and potentially stay ahead of the advances in deepfake technology.

8

Hours of Volodymyr Zelenskyy footage used to train the detector

The detector had 100 per cent accuracy spotting three fake videos of Zelenskyy that altered his mouth movements and spoken words, commissioned from the Delaware-based Colossyan, which offers custom videos of AI actors. The detector also performed flawlessly against the actual deepfake released in March 2022 (*PNAS*, doi.org/grf58z).

The time-consuming training process requiring hours of video is less suitable for identifying deepfakes involving ordinary people or non-consensual videos of sexual acts. "The more futuristic goal would be how to get these technologies to work for less exposed individuals who do not have as much video data," says Boháček.

The researchers built another detector to spot false videos of US president Joe Biden, and are considering making similar models for public figures such as Russia's Vladimir Putin, China's Xi Jinping and billionaire Elon Musk. They plan to make the detector available to certain news organisations and governments. ▮

Medicine

Stretchable sticky plaster repairs punctured lungs

Carissa Wong

A STICKY gel plaster containing the yellow pigment in turmeric can patch up punctured lungs in rats.

Biodegradable gel patches often need to be glued to the body parts they are intended to help repair and can struggle to follow the movement of organs like lungs as they expand and contract.

Juliane Nguyen at the University of North Carolina at Chapel Hill and her colleagues have made a gel patch that should be biodegradable and can stretch up to four times its length without breaking, as well as instantly sticking to organs without needing any glue.

Its stickiness comes from the opposite charges of molecules in the gel and the damaged tissue, which quickly form chemical bonds. It also contains nanoparticles of curcumin – the yellow pigment in turmeric – that are known to be antimicrobial and to reduce inflammation.

To test how well the gel could repair punctured lungs, the team applied patches to three rats with lung injuries and found that they completely restored lung pressure in these animals, while another experiment by the team found that the patch could stretch and contract with the inflation and deflation of rat lungs.

A third test found that patches soaked in a solution containing many exosomes, which are tiny sacs generated by all cells that carry a mix of useful biological molecules, seemed to promote wound healing, compared to patches without these sacs (bioRxiv, doi.org/jp2w).

"This research is very exciting. The unique structure gives the gel great deformability compared to similar gels and it can adhere to moving organs even more strongly than other gels that are stuck by glue," says Malcolm Xing at the University of Manitoba in Canada. ▮

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Palaeontology

Oldest DNA ever recovered reveals ecosystem from 2 million years ago

Michael Marshall

DNA from 2 million years ago collected from sediments in Greenland is the oldest preserved DNA found to date, blowing past the previous benchmark of 1 million years set in 2021.

Eske Willerslev at the University of Cambridge and his colleagues identified DNA from a host of different organisms, allowing them to reconstruct the ecosystem that existed in northern Greenland 2 million years ago. Today, the area is Arctic desert and has few organisms, but back then it was a forest inhabited by hares, reindeer and perhaps even mastodons, the elephant-like animals that once lived in North America.

The find suggests that it will be possible to uncover DNA from much more ancient time periods than previously suspected. "I wouldn't be surprised if it turned out that in the north [the Arctic], we could go twice as far back in time," says Willerslev.

He and his team obtained ancient DNA from the Kap København Formation, a series of layers of sand, silt and mud more than 90 metres thick in total. These were laid down 2 million years ago.

The DNA didn't come from fossilised organisms, but was instead bound to mineral particles in the sediment layers. This helped preserve the DNA, because enzymes couldn't get to it to break it down, says team member Karina Sand at the University of Copenhagen in Denmark.

This environmental DNA came from the whole range of organisms living in the area. The team detected 102 genera of plants. Some still grow in northern Greenland today, like the shrubs *Dryas* and *Vaccinium*. But others no longer live there, like spruce trees (*Picea*), hawthorn (*Crataegus*) and *Populus* flowers. "It is, in fact, a forest," says Willerslev.

> "I wouldn't be surprised if it turned out that in the Arctic, we could go twice as far back in time"

Fewer animal species were identified, probably because they always make up less of the biomass than plants, says Willerslev. Nevertheless, the DNA revealed Arctic hares (*Lepus arcticus*), rodents related to lemmings and muskrats, geese and reindeer.

There was also DNA from an extinct elephant relative, which the team tentatively identified as a mastodon, not a mammoth. Mastodons lived in the Americas for several million years, but hadn't previously been found in Greenland. It isn't known how mastodons might have travelled to Greenland, but they may have crossed sea ice (*Nature*, doi.org/jpzj).

If free-floating DNA can survive this long by binding to mineral particles in cold conditions, it suggests even older DNA may be found in the Arctic and the Antarctic, says Laura Parducci at Sapienza University of Rome in Italy. However, "the diversity of the plants and animals would be far less" in Antarctica, says team member Kurt Kjaer at the University of Copenhagen, because it has been polar desert for so long. ▮

Climate change

Venice may get a respite from rising seas by 2035

THE sea level in Venice may level off in the next decade, giving the city a brief respite from rising water. It turns out that changes in the surface temperature of the Atlantic Ocean are linked to how high the water gets in Venice, and as the North Atlantic enters a cooler phase, it should slow the rising damp.

A combination of subsidence and sea level rise has left Venice about 35 centimetres lower than it was 150 years ago. Continuing sea level rise is expected to push waters up further by the end of the century, by between 30cm and 120cm, which could leave much of the iconic Italian city permanently flooded.

LUIGI COSTANTINI/AP/SHUTTERSTOCK

People wading through a flooded St Mark's Square in Venice, Italy, last December

Rising global temperatures have resulted in sea level rise across the Mediterranean, but it hasn't climbed smoothly. Historical tide and satellite data show a climbing pattern punctuated by periods of two decades or more when sea level rise has slowed or even plateaued.

Now, Davide Zanchettin at Ca' Foscari University of Venice and his colleagues have compared 150 years of sea level data from Venice with data on sea surface temperature variations from the North Atlantic Ocean. They found a correlation between average winter sea level in Venice and sea surface temperature variations in the North Atlantic, which happen over a 60 to 80-year time period, known as Atlantic multi-decadal oscillation.

During cooler Atlantic phases, sea level rise in Venice slowed, and during warmer phases, it accelerated (*Earth and Space Science*, doi.org/jpxb). Zanchettin thinks Atlantic temperature changes influence atmospheric and water circulation patterns in the Mediterranean.

Studies suggest a cold oscillation phase is about to occur, says Zanchettin. "If it does, then our calculations indicate that between now and 2035, the sea level in Venice may level off," he says, with the cold Atlantic phase temporarily compensating for the sea level rise from warming. ▮

Kate Ravilious

Materials

Biogel body armour could stop a supersonic bullet

Carissa Wong

A GEL made of a protein found in human cells can capture particles travelling at supersonic speeds without destroying them on impact, suggesting the material could be used in body armour or for collecting space debris.

Our cells contain a protein called talin that helps them sense and navigate their local environment in the body by changing structure in response to external forces. Benjamin Goult and his colleagues at the University of Kent, UK, have made a talin-based gel that reforms after it is struck by a projectile, allowing the object to be removed unharmed.

"Each talin molecule has 13 'switches' that can unfold when force is applied and these refold after force is removed, enabling shock absorption," says Goult.

The team adapted the ends of three talin switches, then linked these modified molecules together using water and a gelling agent to form a mesh-like structure.

When something hits the gel, the energy unfolds the modified talin switches rather than being converted to heat, as is the case with existing materials, says Goult.

To test this creation, the researchers used a piston to fire particles of basalt, which were between 20 and 70 micrometres wide, at a sample of the gel in front of an aluminium plate. Even when firing the particles at supersonic speeds of 1.5 kilometres per second, the gel prevented them from reaching the plate (bioRxiv, doi.org/jp2t).

The team is now working with a company to develop the gel as a component of body armour. As other proteins labelled with fluorescent markers can bind to talin in its unfolded state, damage to the armour could be identified by adding fluorescent proteins to the gel, says Goult. ▮

Analysis Automated vehicles

Why you may never be able to buy your own self-driving car

Despite many breakthroughs in car automation, private vehicles that need no driver may never reach the market, says **Matthew Sparkes**

JADE GAO/AFP VIA GETTY IMAGES

The Robo-01, an autonomous concept car from Chinese firm Jidu

SOME Mercedes-Benz S-Class cars can drive themselves unaided, as long as you are in a specific car park in Germany. It is somewhat impressive, but disappointing given *New Scientist* proclaimed 15 years ago that a fully driverless car "may not be far off".

Perhaps the most ambitious driverless experiment so far is from US start-up Cruise, which began offering a taxi service in San Francisco this year. Customers are the only occupants and no driver sits ready to grab the wheel. While these cars have randomly stopped and blocked traffic, things have otherwise gone relatively smoothly.

City streets can be challenging to navigate, so Cruise initially only offered rides at night, when streets were quieter, and limited operation to San Francisco, which it has extensively mapped.

It is, nonetheless, proof that driverless cars are possible, and is a vital step to convincing people that the technology's time is near.

There are varying levels of car automation, though, defined by standards body SAE International: level 0 is a conventional car, while levels 1, 2 and 3 include increasing driver aids. Level 4 is full automation in "limited conditions" and level 5 is total autonomy, all the time. At that final level, car-makers could do away with the steering wheel and pedals.

While Cruise certainly meets level 4 – as do trialled taxis from Waymo – there have been no cars on general sale with this capability.

"Getting it to work everywhere, and… in all weather conditions, that's where a lot of the challenges come in," says Toby Breckon at Durham University, UK.

> **"There's an analogy with autopilots in planes. A lot of private planes don't contain autopilots"**

Taxi services can sidestep these problems by controlling when and where cars operate, and pausing operations if problems are spotted, without angering owners.

Breckon says creating AI software to navigate on US streets, which are wide and built for cars, is a different challenge to doing so for narrow European streets or bustling roads in parts of Asia. Making different models for every market is prohibitively expensive, so the software needs to be capable of handling all of it, in all weathers. Anything less could mean cars struggle to cope.

Add to this the uncertain legal issues around who is at fault if a driverless car kills someone or damages property, plus unknown market demand, and launching a private autonomous car is a huge financial risk as well as a thorny technical challenge.

Private car automation isn't being entirely neglected, however, as is shown by Mercedes-Benz's announcement this month that its S-Class model will now offer level 4 automation, albeit only in one car park at Stuttgart airport, where it can park itself with help from sensors dotted around the area.

Chinese start-up Jidu also promised in June that it would launch a level 4 car called the Robo-01 this year. That deadline has now been extended to 2023.

Other companies have faced criticism over their claims. Tesla named its driver-assist software "Autopilot" despite its meeting only level 2 of the SAE categories and is facing legal challenges over phrases like "self-driving" in its marketing material. Tesla didn't respond to a request for comment.

Given the hurdles, general sales of a level 4 car are likely to still be more than five years away, and firms may never actually sell them, says Breckon. "There's an analogy with autopilots in planes, and a lot of small, private planes that people own individually don't contain autopilots."

Another option is that firms only lease these cars, retaining control of what they can do, and where and when. "If, suddenly, there's a spate of pedestrian deaths, they can actually just turn [autonomous driving] off," says Breckon. ▮

Evolution

Diversity of species helped mammals shrug off dinosaur-killing asteroid

Riley Black

MAMMALS survived the asteroid that wiped out the dinosaurs by evolutionarily hedging their bets, generating an array of varied species that set them up to weather the prehistoric apocalypse, according to a new analysis.

By looking at how ecosystems in prehistoric North America changed – or stayed the same – Jorge García-Girón at the University of León, Spain, and his colleagues hoped to gain some insight into why mammals and other small creatures thrived after the impact 66 million years ago, while birds were all that remained of the dinosaurs.

"I do not believe that selectivity favouring small-bodied animals alone can explain the difference between survival and extinction between mammals and dinosaurs," says García-Girón. The real picture is much more complex and has to do with the spread of different diets, behaviours and ecological niches that animals had before the impact, he says.

Drawing on more than 1600 fossils of various North American dinosaurs, fish, amphibians, reptiles, birds and mammals, the team estimated the niches each extinct species occupied. For each species, the researchers assigned a body size, habitat and diet, plugging this information into a computational model developed by ecologists to track how food webs shift over time.

The team found that dinosaurs present in North America 66 million years ago more or less resembled those of 18 million years earlier, representing a form of ecological stability. Mammals, meanwhile, persistently pushed the envelope of adaptation, evolving into a vast array of climbing, gliding, swimming, burrowing and other forms during this period (*Science Advances*, doi.org/jpxf).

Contrary to some previous studies that proposed a decline in the number of dinosaur species in the time leading up to the impact, the researchers found no such dip. If anything, dinosaurs like *Tyrannosaurus rex* and *Triceratops* were filling the same roles their ancestors did millions of years earlier. Mammals, on the other hand, were more flexible.

Artist's impression of the day an asteroid killed the dinosaurs

SERPEBLU/SHUTTERSTOCK

"It not only amazed me how mammals managed to thrive in the highly complex, and probably dangerous, dinosaur-dominated ecosystems," says García-Girón, but also how rapidly our ancestors moved into vacant niches after the asteroid hit.

"Dinosaurs going extinct is certainly a captivating story, but they were just one of the many taxa that were dramatically affected by the... mass extinction," says Lucas Weaver at the University of Michigan. The study brings together the data various researchers have collected into a new theoretical model that can continue to be assessed with new discoveries, says Weaver, and such ecosystem-wide approaches are likely to provide the next big insights into what happened before and after this cataclysmic event. ▮

Technology

Heat pump uses a loudspeaker and wet paper to cool air

A HEAT pump that uses sound to deliver cooling could one day be more efficient than existing designs.

Heat pumps cool buildings by removing heat from the inside and pushing it outside, and they can also heat an area by reversing the process. They are typically more efficient than conventional heating and cooling devices.

Guy Ramon at Technion-Israel Institute of Technology and his colleagues wanted to see if they could make an even more efficient heat pump by using sound waves to change temperature instead of mechanical parts, which take more energy to move. Thermoacoustic heat pumps have been built before, but they haven't been efficient or powerful enough to be useful.

The team's thermoacoustic heat pump consists of a metal tube filled with nitrogen, connected on one end to a loudspeaker that plays a sound roughly 100 times more powerful than the noise from a chainsaw. The sound waves cause the nitrogen to compress and expand. When it expands towards the loudspeaker end of the tube, it gets cool, much like how perfume sprayed from a bottle cools as it dissipates. "Inside of the tube, it's as loud as rock and roll. Outside, it is dead silent," says Ramon.

The heat pump also uses water via a stack of wet paper strips placed at the other end of the tube to the speaker. When the nitrogen condenses and expands, it evaporates some of this water and turns it into vapour, releasing energy and cooling the gas further.

"For every unit of power the heat pump consumes, it can remove up to four times that much heat"

The new device is a proof-of-concept model that has about a hundredth times the power of conventional heat pumps, but it works efficiently, says Ramon. For every unit of power it consumes, it can remove up to four times that much heat, comparable to household air conditioners. The team presented the device on 20 November at the annual meeting of the American Physical Society's Division of Fluid Dynamics in Indianapolis, Indiana. ▮

Karmela Padavic-Callaghan

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Animal behaviour

Beeswax features in a surprising number of animal diets

Ryan Truscott

MANY animals in southern Africa feed on beeswax and, by doing so, they help maintain a unique partnership between honey-hunting humans and birds that lead them to wild bees' nests.

DAVID LLOYD-JONES

A honey badger *(Mellivora capensis)* feasting on beeswax

Until now, it was thought that very few animals apart from greater honeyguides (*Indicator indicator*) could digest beeswax – a high-energy food that the birds obtain as a reward from humans who break open bees' nests.

David Lloyd-Jones at the University of Cape Town, South Africa, and his colleagues set up camera traps at 26 sites in the densely wooded Niassa Special Reserve in Mozambique where honey had been harvested and wax left aside by honey-hunters from the Yao community.

They observed nine other species feeding on the wax, including honey badgers, African civets, two other species of honeyguide that don't cooperate with humans and five animals not previously known to eat wax: yellow baboons, slender and Meller's mongooses, striped bush squirrels and crowned hornbills (*Proceedings of the Royal Society B*, doi.org/jpx6).

In most cases, the greater honeyguide that led the humans arrived at the wax reward long before any competitors did. The other animals that ate the wax edged out the honeyguide's main rivals – other, late-arriving greater honeyguides – thus helping the partnership persist by favouring birds that cooperate with humans. ▮

Health

Smoking and drinking alcohol are linked to our genetics

Carissa Wong

NEARLY 4000 genetic variants have been linked to smoking or drinking habits, such as how many alcoholic drinks someone has a week or the age they take up smoking.

The decision to smoke or drink alcohol can be affected by various factors, including social situations and public health policies, but our genetics are also thought to play a role.

To investigate, Dajiang Liu at the Penn State College of Medicine and his colleagues analysed the genomes of people who took part in 60 studies in the US, Australia and Europe (*Nature*, doi.org/grd2td).

The participants were of African, North and South American, East Asian and European descent. Similar past studies were smaller and were largely made up of people of European descent, says Liu.

The team compared the participants' genomes with their self-reported smoking habits and alcohol consumption.

Results suggest that 2468 genetic variants are linked to regularly smoking, defined as smoking every day.

The study also links a further 243 variants to how many cigarettes a person smokes a day, 206 variants to whether a person will give up smoking and 39 variants to the age when someone starts the habit, which varies from person to person. The researchers didn't look at other forms of tobacco intake, such as smoking cigars.

They also identified 849 additional genetic variants that are linked to how much alcohol a person drinks per week.

2468

Genetic variants are linked to smoking cigarettes every day

Some of the variants they identified for smoking and alcohol consumption are in genes involved in brain signalling.

Alcohol consumption, for example, is linked to a gene called *ECE2*. This is involved in processing neurotensin, a molecule that regulates signalling of the hormone dopamine, which is involved in the reward system that can cause addiction.

Meanwhile, the number of cigarettes smoked per day is linked to variations in a gene called *NRTN*, which influences the survival of neurons that secrete dopamine.

In another part of the study, the team used this genetic variant information to predict smoking habits and alcohol consumption in a separate group of 6092 people of European descent living in the US.

"These risk scores predicted smoking and drinking behaviour pretty well," says Liu. Eventually, such risk scores could be used in medical settings, for example to gauge whether someone may be genetically predisposed to smoke or to drink an unhealthy amount, he says.

When these European-based risk scores were applied to almost 4000 people of African, East Asian or North or South American descent, however, the results were less accurate, meaning we may need to develop separate risk scores for people with different ethnic ancestries, says Liu.

The work demonstrates the power of using large samples from multiple ancestry groups for this kind of research, says Joel Gelernter at Yale University. "It's overall a substantial advance in our understanding of the genetics, and therefore the biology, of smoking traits and alcohol drinks per week."

That said, even larger samples would let the team assess genetic variants that are known to occur in fewer than 1 in 1000 people, which Liu says could be done as part of future research projects. ▮

WESTEND61/GETTY IMAGES

Genetic risk scores could help predict alcohol consumption

Biology

Lager microbe found on college campus

THE elusive forerunner of the yeast species used in modern lager beer has been found in Europe for the first time. The discovery in Irish soil suggests it was present in Europe during the switch from ale to lager-style brews at the end of the Middle Ages.

The ancestor, *Saccharomyces eubayanus*, was first found in the Patagonian Andes in 2011 and since then has turned up in North America, China and New Zealand. But it had never been found in Europe until Geraldine Butler at University College Dublin in Ireland and her students sampled soil on their campus. Genomic sequencing revealed strains of *S. eubayanus* (*FEMS Yeast Research*, doi.org/grdvfr).

Butler and her team hope the find will lead to a new brew with the ancient yeast. **Corryn Wetzel**

Technology

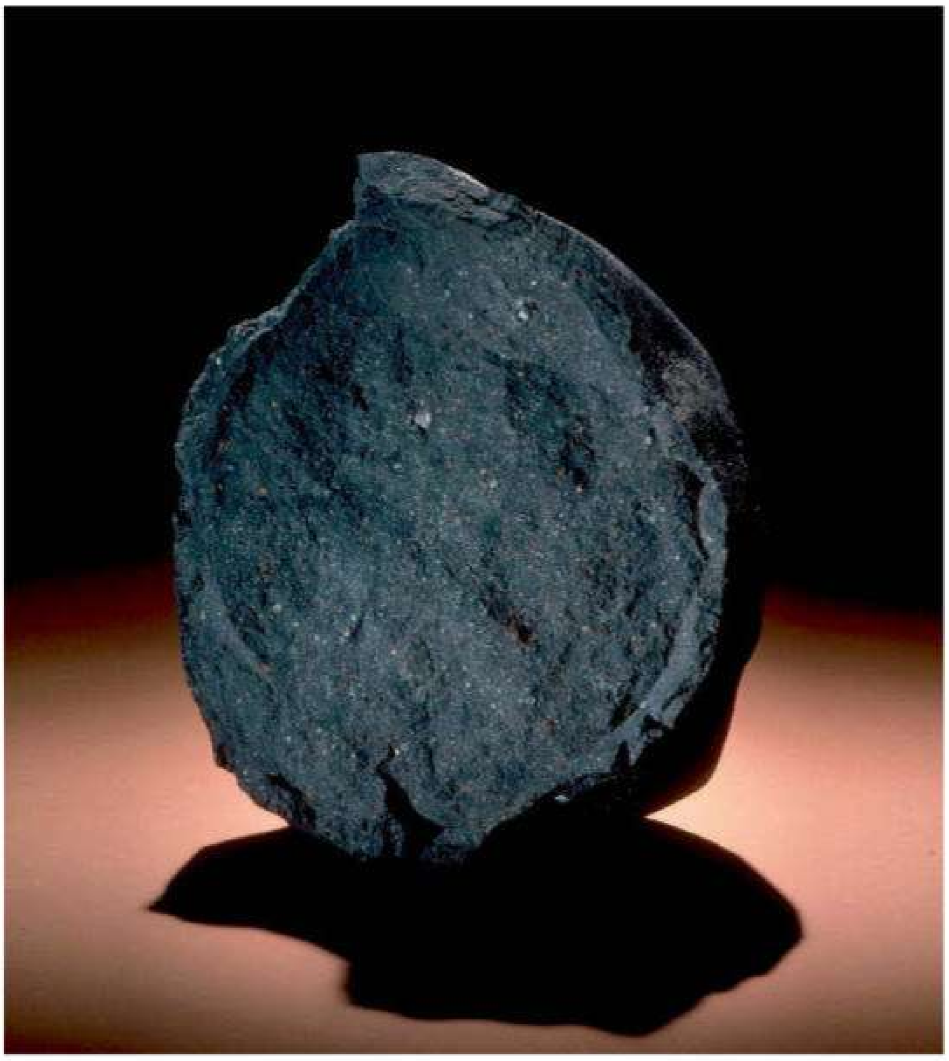
Four-legged robot can heal if wounded

A FLEXIBLE quadruped robot can sense when it is damaged and stop moving until it heals.

Hedan Bai at Northwestern University in Illinois and her colleagues made a simple soft robot that can detect when it is harmed and then mend itself before continuing to move.

The robot measures about 12 centimetres long and is shaped like the letter X. It moves using compressed air that is pushed through its body, making it undulate and lift its four legs.

The top of the robot is covered in a layer of self-healing sensors, made from a transparent rubbery material, that track the robot's motion. If a sensor is cut, its exposed sides become chemically reactive, allowing it to fuse back together (*Science Advances*, DOI: 10.1126/sciadv.abo3977). **Karmela Padavic-Callaghan**



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Solar system

Did gamma rays generate building blocks of life in space?

RADIOACTIVE meteorites may have helped create key chemicals for life a few million years after the solar system was formed.

Amino acids are molecules that combine to form proteins and so are vital for life as we know it. They have been found in carbonaceous chondrites, a type of radioactive meteorite, leading some people to suggest that the parent bodies that spawned these space rocks may have had a role in the origins of life.

Exactly how these amino acids could be created in meteorites has remained a mystery, but now Yoko Kebukawa at Yokohama National University in Japan and her team have shown that some could have been synthesised by chemical reactions driven by gamma rays.

They mixed solutions of ammonia, formaldehyde and methanol in water, in proportions similar to those thought to be found on meteorite parent bodies. They then exposed them to gamma rays produced by a sample of cobalt-60. This acts as a stand-in for the same rays known to be produced by radioactive isotopes found in meteorites, such as aluminium-26, which are difficult to work with in the lab due to their long half-lives. The team measured the amino acids produced by the resulting reaction and found there was a similar proportion of them to that in the Murchison meteorite (pictured), a 100-kilogram rock that landed in Australia in 1969 (*ACS Central Science*, doi.org/grdzqq).

However, José Aponte at NASA's Goddard Space Flight Center in Maryland says it will be a long time before we can definitively point to the reaction pathway that synthesised amino acids billions of years ago. **Jacklin Kwan**

Really brief

MISKA PUUMALA/SHUTTERSTOCK

Quantum hook-up for supercomputer

Finland's first quantum computer, HELMI, has been connected to LUMI (pictured), the third-fastest supercomputer in the world and fastest in Europe. It may be a step towards a new type of computing that brings traditional and quantum computers together to quickly solve complex problems.

Dino's weapon was used on own kind

Damage to the spikes on the back of a fossil of a *Zuul crurivastator* hints that these armoured dinosaurs didn't use their tail clubs to fend off tyrannosaurs, they used them on each other. It could have been much like modern animals using horns or antlers to claim territory or mates (*Biology Letters*, doi.org/jptf).

AI detects diarrhoea from toilet sounds

An artificial intelligence can detect diarrhoea with 98 per cent accuracy by analysing sounds from toilets, a meeting of the Acoustical Society of America was told on 5 December. It could help track outbreaks of diseases like cholera if microphones and AI detector boxes were fitted in toilets.

CONFLICT APPEAL

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HELP US DELIVER MEDICAL CARE BEYOND THE FRONTLINES

An MSF medic treats a patient onboard the medical train. Photograph © Andrii Ovod/MSF

CHRISTOPHER STOKES IS COORDINATING MSF'S MEDICAL WORK IN UKRAINE

23 October 2022

"On 10 October I had just left the train station in Dnipro, eastern Ukraine, when the car started shaking. A second later, we heard the blast from the first missile. By the time we reached the office, we'd felt four more shockwaves from strikes. Since then, there have been regular waves of bomb attacks targeting infrastructure and civilian areas.

We're now gearing up for the possibility that the electricity will go off across Ukraine as a result of these ongoing attacks. That will have drastic knock-on effects on hospitals, healthcare and people's lives. People are heading into winter with the risk there will be no electricity, heating or hot water.

We're doing our best to prepare. We're helping a number of hospitals near the frontline get ready. We're running mobile clinics in areas previously under Russian occupation where people have had no access to the medicines they need for months. MSF operates a specially designed medical train that evacuates patients from near the frontlines of the fighting to safer areas and we're looking at ways to keep that running, even if the electricity fails. It's been kitted out with an intensive care unit and inpatient carriages. To date, we've evacuated 1,851 patients in 60 trips, most of them suffering from blast injuries and shrapnel wounds.

Last weekend we carried one family on the train who needed to be evacuated from the war zone. They had returned to their home in Nikopol on 5 October after having fled the war months earlier. On 6 October, their house was hit by a shell. One of the daughters was badly injured and ultimately had to have both legs amputated. She was only six years old.

The Ukrainians are doing the bulk of the medical work in this war. Our role is about filling the gaps. With these latest attacks, people's medical needs are growing, and it's vital we are here."

MSF'S WORK IN CONFLICTS

In conflicts around the world, MSF teams are working around the clock to treat trauma injuries, conduct surgeries and provide lifesaving medical care to the victims of bombings and indiscriminate attacks.

Yet our work involves much more than frontline trauma care. Conflict has a devastating ripple effect on all aspects of healthcare. In countries such as Ukraine, Yemen and South Sudan, MSF is saving lives beyond the frontlines. We're running nutritional programmes for malnourished children, treating infectious diseases and helping women to give birth safely.

£47	could provide a folding stretcher for transporting injured patients
£456	could cover the cost of an MSF doctor working in a field hospital for six days
£194	could pay for a sustenance kit to help mothers provide babies with essential nutrition

THANK YOU

100% of funding for our work comes from private donors. It's your support that enables us to continue providing medical care.

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CALL 0800 055 79 84

Or search 'MSF CRISIS'
to make an online donation

This appeal will fund MSF's work in conflicts where people are in urgent need of medical care.

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I WOULD LIKE TO MAKE A DONATION OF £

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Please fill in this form, place in an envelope and return postage free to:
FREEPOST RUBA-GYZY-YXST, Médecins Sans Frontières (MSF), Bumpers Way, Bumpers Farm, Chippenham, SN14 6NG. Alternatively, you can phone **0800 055 79 84** (open 8am – 10pm 7 days a week) or make your donation online by searching **'MSF CRISIS'**.

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NB: Please let us know if your name, address or tax status changes, or if you would like to cancel this declaration, so that we can update our records.

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Your support is vital to our work and we would like to keep you informed with first-hand accounts from our staff and patients about the lifesaving impact your support is having, from combatting epidemics to providing emergency surgery.

We won't allow other organisations to have access to your personal data for marketing purposes and we won't bombard you with appeals.

By supporting MSF, you will receive our quarterly magazine Dispatches, event invitations and occasional emergency appeals with requests for donations by post. You can change how you hear from MSF UK by emailing **uk.fundraising@london.msf.org** or calling **020 7404 6600**. Visit our privacy notice for more: **msf.org.uk/privacy.**

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Review of the year 2022

Nuclear risk
New danger posed by Russia's invasion of Ukraine p20

Loss and damage
The COP27 climate talks set a challenge for high-income nations p22

Take heart
The rise of xenotransplants raises hope p23

Galactic glory
The joy of the James Webb Space Telescope p26

Growing drought
Impact of low rain in Europe will be felt for years to come p28

DIGITALGLOBE/GETTY IMAGES

The most explosive volcano this century

THE eruption of the Hunga Tonga-Hunga Ha'apai volcano in Tonga on 15 January was the most powerful of the 21st century so far.

The volcano, which is 20 kilometres wide at its base and mostly lies underwater north of Tonga's main island, Tongatapu, erupted with a volcanic explosivity index of 6, making it the most explosive eruption since that of Mount Pinatubo in the Philippines in 1991. The blast shot ash 57 kilometres into the sky.

Tsunami waves caused by the explosion were initially 90 metres high and were still up to 18 metres high by the time they reached some parts of Tonga, says Shane Cronin at the University of Auckland in New Zealand, who went to Tonga to assess the damage in March.

Four people in Tonga were killed by the tsunami. The reason the death toll wasn't higher is that Tongans are very aware of tsunami risk, and most people swiftly evacuated to the highlands when they saw and heard the volcano erupting, says Cronin. ▮

Alice Klein

Ukraine invasion

A new kind of nuclear war

Military attacks on nuclear power plants in Ukraine by Russian troops shocked the world and could lead to new reactor designs, says **Matthew Sparkes**

DIMITAR DILKOFF/AFP VIA GETTY IMAGES

RUSSIA'S invasion of Ukraine on 24 February was an extraordinary event for many reasons, yet it also marked a dangerous first in the history of warfare: a country with a large and advanced network of nuclear power plants was turned into a battleground.

Ukraine contains Chernobyl, the infamous site of the 1986 reactor disaster, as well as Europe's largest nuclear plant, Zaporizhzhia. In all, Ukraine has the seventh largest nuclear power production capacity in the world, plus four active power stations with a total of 15 reactors.

The initial concern around the potential for collateral damage of these plants grew as Russian troops occupied them. Chernobyl was captured by Russian forces in the first days of the war and was held until the end of March, during which time safety was put at risk as troops hindered staff entering and leaving the plant. The Zaporizhzhia plant has also been held by Russian forces since early in the war and has been hit by Russian artillery. The electricity supply to all four of Ukraine's nuclear plants, which powers vital cooling systems that maintain safety, has also been interrupted by attacks on the nation's power grid.

Kent Harries at the University of Pittsburgh says that all these new risks will have to be considered when designing nuclear power plants in the future, just as previous security events informed older designs.

"From now on, we'll have to consider large-scale nuclear terrorism when designing reactors"

"In North America, we design the nuclear island [the heart of a reactor] for physical loadings that are technically secret, but they're basically aimed at [stopping] either missiles or some sort of a 9/11-type scenario," he says. "Looking into the future, yes, I think we will probably be considering different risks."

Many of Ukraine's reactors date back to the 1980s, but Harries says that newer designs are already more resilient to the sort of attacks seen during Russia's invasion.

A Ukrainian exercise in the city of Zaporizhzhia on 17 August, in case of a possible nuclear incident at the nearby power plant

For instance, the latest AP1000 designs used in the US have water held above the reactor that can be released even without electrical power to safely shut down in the event of a problem. These would prevent a meltdown like that seen in Fukushima, Japan, in 2011, when a tsunami knocked out the plant's emergency generator system, leaving safety measures without power.

Olena Pareniuk at the Ukrainian Institute for Safety Problems of Nuclear Power Plants, who works in the Chernobyl exclusion zone and saw her research destroyed during the occupation, says that proposed small modular reactors (SMRs) are likely to be a less risky option in the future.

"It's obvious that, from now on, we'll have to take the possibility of large-scale nuclear terrorism into account when designing reactors," she says. "Probably, building smaller units, like SMRs, will be one of the solutions, as their impact on the environment in case of an accident or attack will be smaller."

But Harries says that no amount of protection and built-in safeguards will be enough when faced with a determined attacker. "The cynical engineer in me thinks, sadly, we will come up with ways if we want to cause damage." ▮

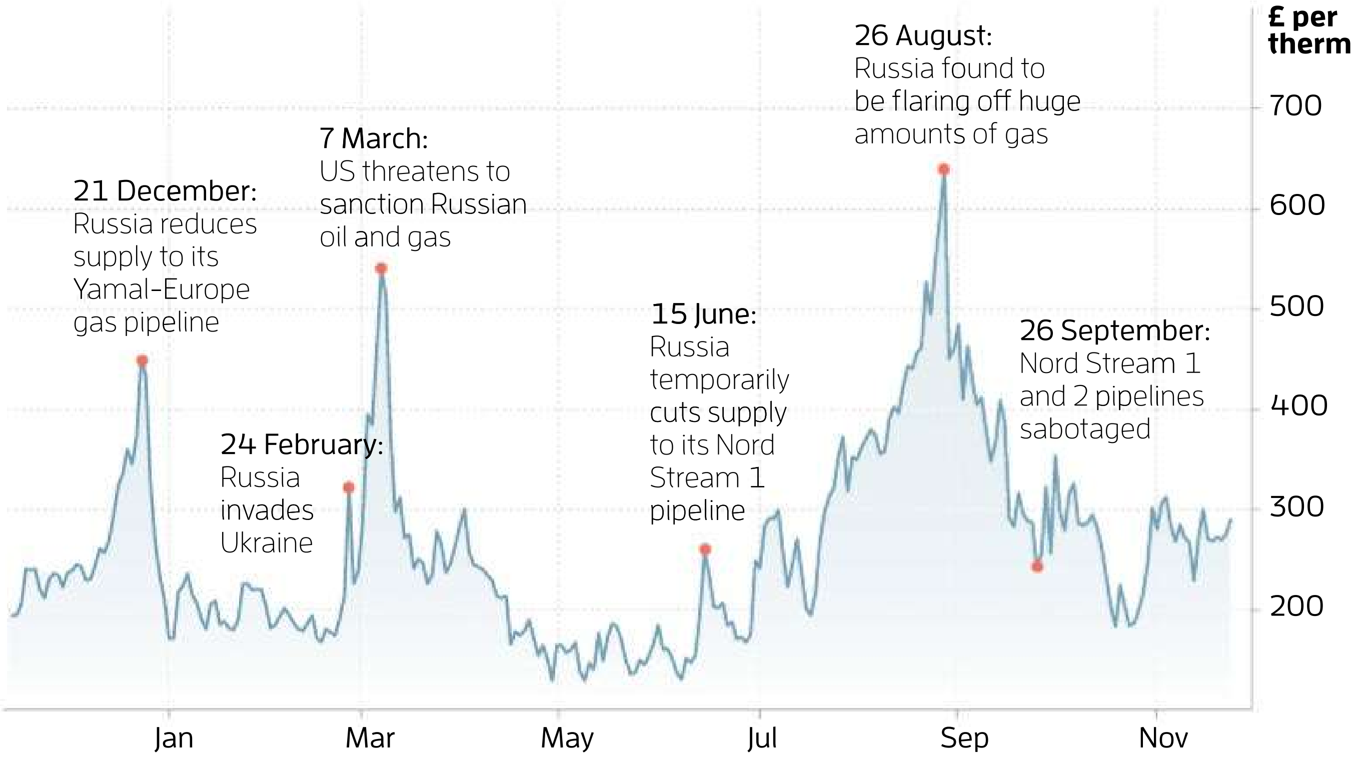
15

The number of nuclear reactors in Ukraine

Energy

The Russian gas rollercoaster

Russia's invasion of Ukraine and subsequent events have had a huge impact on the cost of gas in Europe



SOURCE: The UK gas price is used as a benchmark across Europe. One therm is the equivalent of around 29 kilowatt-hours. Data from tradingeconomics.com

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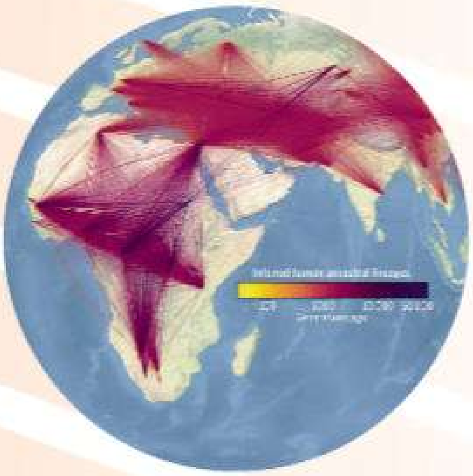

Genetics

Family tree of humanity shows how we are all related

Michael Le Page

IT IS one thing to work out your own family tree. It is another to create one for all of humanity. But biologists have made a start: in February, Gil McVean at the University of Oxford and his colleagues unveiled a family tree of humanity based on 3601 modern genomes and eight ancient genomes.

"Perhaps the most positive aspect of the response I've had is that many people are starting to see human genetic variation in terms of the underlying genealogy, through which we are all related, rather than discrete 'populations'," says McVean.

"Because we can now build the genealogy of everyone, we can talk about ourselves in this rich and nuanced way, rather than resorting to simplistic labels like 'African' or 'European'," he says.

This initial attempt at a family tree (visualisation pictured) is obviously far from complete because it doesn't include all individuals and their relationships. But it does reveal the main structure of the tree, going all the way back to distant ancestors that lived in Africa 2 million years ago.

As more genomes are sequenced and included in such analyses, the human family tree will become ever more comprehensive. But there are fundamental limits on how complete it can be, says McVean, because we share DNA with more and more people as we go back in time. ▮

WOHNS ET AL. (2022)

Climate change

COP27 sets up next climate battle

A deal to compensate nations for climate-related damage raises a tricky question: who pays?

Madeleine Cuff

THE COP27 climate summit closed in November with many people celebrating a historic agreement to create a dedicated fund to help vulnerable countries cope with the financial losses of climate change.

The loss and damage fund marked a major win for the conference, which was otherwise marred by poor organisation and scant progress in cutting greenhouse gas emissions.

But agreeing to a fund is just the start. Next year, negotiators will gather at COP28 in Dubai to discuss the specifics of how it will work, including how much money will need to be raised and where from. Expect fireworks.

"Right now, all we have is an empty bucket – we need to make sure it gets filled," says Mitzi Jan Tonelle, a climate activist in the Philippines.

In Egypt, the European Union said it would only agree to a dedicated loss and damage fund if it was supported by a "broad donor base" of countries, namely a group of higher-emitting nations that, under UN rules, aren't usually expected to provide climate finance, such as China and petrostates like Qatar and Saudi Arabia. Steering this demand for cash will be a tricky mandate for COP28 host nation the United Arab Emirates, one of the world's largest oil producers.

"We have to be honest about the expectations around finance," says Kaveh Guilanpour, a former climate negotiator who is now at the US-based Center for Climate and Energy Solutions. "Limiting funding only to a subset of countries, particularly the G7, is not going to result in the amount of funds necessary."

And countries alone may not be enough to finance the fund, especially as high-income nations tighten their belts in response to rising inflation and an energy crisis.

Those concerns are fuelling a push for COP28 to consider alternative sources of financing, with fossil fuel firms in the crosshairs. Speaking to delegates at the start of COP27, the prime minister of Barbados, Mia Mottley, said oil and gas companies should be made to pay for the climate loss and damage they helped to cause.

"How do companies make $200 billion in profits in the last three months and not expect to contribute at least 10 cents in every dollar of profit to a loss and damage fund?" she asked.

It is a stance backed by UN Secretary-General António Guterres, who, in September, called on all advanced economies to tax the windfall profits of fossil fuel companies.

Other finance could come from overhauling the World Bank and the International Monetary Fund.

These organisations, alongside other multilateral development banks (MDBs), should be forced to channel more money into climate projects in lower-income countries, on more favourable terms, said Mottley.

This could include offering cheap financing for renewable energy or climate resilience schemes, for example, or allowing countries hit by natural disasters to pause debt repayments while they recover. Mottley's ideas gathered steam at COP27, which saw an agreement for MDBs to "define a new vision" that was "fit for the purpose of adequately addressing the global climate emergency".

For decades, high-income, polluting nations have resisted attempts to establish a dedicated funding regime for loss and damage. Now they have relented, big emitters around the world will be watching nervously for what comes next.

> "How do oil and gas companies make $200 billion in profits in three months and not expect to pay in to a loss and damage fund?"

PETER DEJONG/AP/SHUTTERSTOCK

COP27 protesters in Sharm El Sheikh, Egypt, on 18 November

Space exploration

NASA's asteroid collision test is a smashing success

Leah Crane

ON 26 September, after travelling 11 million kilometres from Earth in nine months, NASA's Double Asteroid Redirection Test (DART) craft slammed into the space rock Dimorphos. The goal was to see if we could change an asteroid's path by flying a probe into it – and it was an unmitigated success.

Dimorphos is a small moonlet that orbits a larger asteroid called Didymos. Before the impact, Dimorphos circled Didymos once every 11 hours and 55 minutes. The crash moved it slightly closer and now an orbit takes only 11 hours and 23 minutes.

Images taken after the crash showed huge clouds of dust and debris blasted off the smaller asteroid, creating a recoil effect that pushed it closer to Didymos than if the impact hadn't resulted in this debris.

While Dimorphos and Didymos pose no danger to Earth, this success demonstrates that if we were to spot an asteroid heading our way, crashing a spacecraft into it might shift its trajectory by just enough to make it miss Earth.

Figuring out exactly what happened within the asteroid when DART hit it will help us design those potential future missions to keep our planet as safe as possible. ▮

Dimorphos and the larger Didymos as they appeared after the DART crash

ASI/NASA

JOE CARROTTA/NYU LANGONE HEALTH

Surgeons trial transplanting a pig heart into a brain-dead person

Medicine

First person to get a pig heart is step towards routine xenotransplants

Grace Wade

ON 7 January, David Bennett, a 57-year-old with terminal heart failure, became the first person to receive a genetically modified pig heart. While he died two months later, his surgery still marked a significant step forward.

Several months after Bennett's procedure, surgeons at NYU Langone Health in New York transplanted modified pig hearts into two brain-dead people on life support. The hearts pumped blood for three days before the researchers ended the study.

Xenotransplantation, the use of animal organs in another species, had only been done in non-human primates until 2021, when two pig kidneys were transplanted into a brain-dead man on life support. "To take that next step towards making [xenotransplantation] a reality, we felt we needed to do this in a human," says Douglas Anderson at the University of Alabama at Birmingham, who was involved in that work.

Bartley Griffith at the University of Maryland and his team felt the same, hence Bennett's transplant.

Since Bennett's death, they have been reviewing his tissues to try to understand what went wrong. Like any transplantation, a key threat in xenotransplantation is rejection – when the immune system attacks the organ. Pigs bred for this purpose undergo genetic modifications to make them more compatible with our immune system. The pig heart Bennett received had 10 mutations introduced. He showed no obvious signs of rejection post-mortem.

Bennett may have died due to complications from a pig virus called porcine cytomegalovirus. During routine tests, doctors detected the virus in Bennett about 20 days after his transplant, despite testing the heart four times pre-surgery. The pathogen was probably lying dormant in the organ and the immunosuppressing drugs Bennett was taking allowed it to reactivate, says Griffith.

> "Xenotransplanation is no longer a vision. It actually happened and I think we can make it better"

When Bennett showed signs of decline, doctors treated him with an antibody serum in the hope this would attack the virus.

We all have antibodies against the antigens found in a range of other animals, which is why Bennett was on specific immunosuppressing drugs, says Griffith. The antibody serum, which came from a human, could, in theory, inadvertently introduce these antibodies into the pig heart. However, there was no evidence of antibody-induced injury in later studies on Bennett's pig heart.

In the future, Griffith says they will use more sensitive tests when screening non-human organs and choose antibody treatments with minimal anti-pig antibodies.

It may be more than a decade until xenotransplants are available, but broader trials could begin in the next few years, says Anderson.

"[It] is no longer a fantastic vision," says Griffith. "It's actually happened. I think we can just iterate it and make it better." ▮

Coronavirus

Covid-19 responses shift gear

From zero covid to "living with the virus", strategies varied around the world

New Scientist staff

WITH vaccinations lowering covid-19 death rates, many countries chose to end almost all other measures to control the spread of the coronavirus in 2022 – but the virus is still causing waves of illness worldwide.

Early in the year, some nations began to abandon mitigation measures. Towards the end of February, Iceland's strategy shifted from zero covid to "herd immunity", which it hoped to achieve by allowing SARS-CoV-2 to spread while shielding vulnerable people. Days later, Iceland's daily new reported infections reached the equivalent of 8154 cases per 1 million people, more than double seen a month earlier.

The approach was controversial, but this kind of strategy was eventually applied throughout Europe as countries lifted their restrictions, says Francois Balloux at University College London.

The start of the year also saw the omicron variant fuel a worldwide surge in cases, particularly in Hong Kong, which had had few infections up to this time and hadn't vaccinated many of its older people. Hospitals were overwhelmed, leading to exceptionally high death rates.

As omicron swept through the UK, a record number of infections was recorded in England in January and then again in March. The UK government's plan for "living with covid" saw legal self-isolation requirements end in February and, from April, those who tested positive were no longer officially advised to stay at home.

As widespread testing ended in the country, it became harder to track the virus's impact. But according to the UK's Office for National Statistics, which has continued its testing surveys, 1 in 55 people outside of healthcare settings in Scotland, Northern Ireland and Wales had the virus in early November, and 1 in 60 people did in England. At that time, an estimated 2.1 million people in the UK had long covid symptoms.

"I think we've seen over the last year that the current vaccination strategy alone isn't sufficient to keep covid at bay," says Kit Yates at the University of Bath, UK.

The US and many other countries also dropped covid-19 measures throughout the year, with Australia and New Zealand fully reopening their borders in February and July, respectively.

China, however, continued its zero-covid approach, with infected people made to go to quarantine camps. That only changed in December, when protests against the economic and social costs of the strategy forced a rethink.

In the face of waning immunity and an ever-evolving virus, it is clear that herd immunity won't be possible anywhere without better vaccines. Going into 2023, big questions remain over the long-term health impacts of the virus and the best way to manage successive waves of infection. ▮

PHILIP FONG/AFP VIA GETTY IMAGES

Lantern-style covers meant to protect diners at a hotel in Tokyo, Japan

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Particle physics

W boson surprise throws a spanner into standard model

Alex Wilkins

A SHOCK measurement of the mass of a fundamental particle called the W boson ignited the physics world in April, as it appeared to flout the standard model of particle physics.

Hundreds of papers have been written since then to try to explain the result, which seems to defy our best theory of how the universe works. Experiments have been proposed to confirm the findings, while the facts and figures have been pored over to look for possible mistakes in the data from the Tevatron collider at Fermilab in Illinois. "A lot of what happened in the first three months was an information transfer," says Ashutosh Kotwal at Duke University in North Carolina, who led the Collider Detector at Fermilab (CDF) experiment that produced the result.

Because it was so different from past measurements, for example those at the Large Hadron Collider (LHC) near Geneva, Switzerland, much of the analysis has focused on identifying procedural differences between CDF and the LHC's ATLAS and LHCb experiments. The LHC collides electrons and their antimatter counterparts, positrons, whereas the now-defunct Tevatron used protons and antiprotons.

"The response has been very cautious because of the differences between the different measurements," says Chris Hays at the University of Oxford. But overall, the particle physics community has been positive, he says.

2028

When an upgraded Large Hadron Collider could seek new particles

People are already working to reanalyse the data to rule out any biases or mistakes linked to these factors, says Hays. They are also attempting to combine the various measurements into one, which is difficult due to the significant experimental differences.

Apart from reinspecting existing data, some people have suggested ideas that could explain the anomalous W boson mass by suggesting new particles like extra Higgs bosons, the fundamental particle that, through the Higgs field,

gives particles like the W boson their mass. These extra particles include new kinds of electrically charged Higgs or ones that could be responsible for dark matter.

New particles like these could be found by future particle accelerators, such as an upgraded LHC that is due to fire up in 2028, or even by telescopes through high-energy gamma rays and antiprotons.

But even without hunting for new particles, the next precise measurement of the W boson mass, due to come from LHCb in the next year or so, could shed light on the discrepancy. Beyond that, future LHC experiments will be able to improve on the precision of the CDF result. "Given time, I think the LHC can make a measurement that is comparable or even more precise," says Guy Wilkinson at the University of Oxford, who works on LHCb.

The CDF result has put the spotlight on the W boson mass, says Wilkinson, who believes it wasn't seen as a priority before. "I think it's really got people excited and the amount of resources and efforts being devoted to it now has ramped up," he says. ▮

Climatology

Extreme temperatures and increasing ice melt unleashed at the poles

James Dinneen

MINUS 12°C would be a frigid afternoon almost anywhere except Antarctica. But when the temperature hit -12.2°C on 18 March at Concordia research station, 1600 kilometres from the South Pole, it was the highest reading recorded at that location.

The exceptional conditions were driven by atmospheric rivers that have brought warm, wet air to the Antarctic continent more frequently in recent years, says Catherine Walker at the Woods Hole Oceanographic Institution in Massachusetts. She says human-caused warming could be making these currents more intense.

A few weeks earlier, another Antarctic record fell, as sea ice reached its lowest minimum extent on record, continuing a pattern of decline driven by warmer oceans.

Freshwater ice wasn't faring too well either. The southern summer ended with the collapse of the Los Angeles-sized Conger ice shelf, an indication that ice in east Antarctica is more vulnerable than we thought.

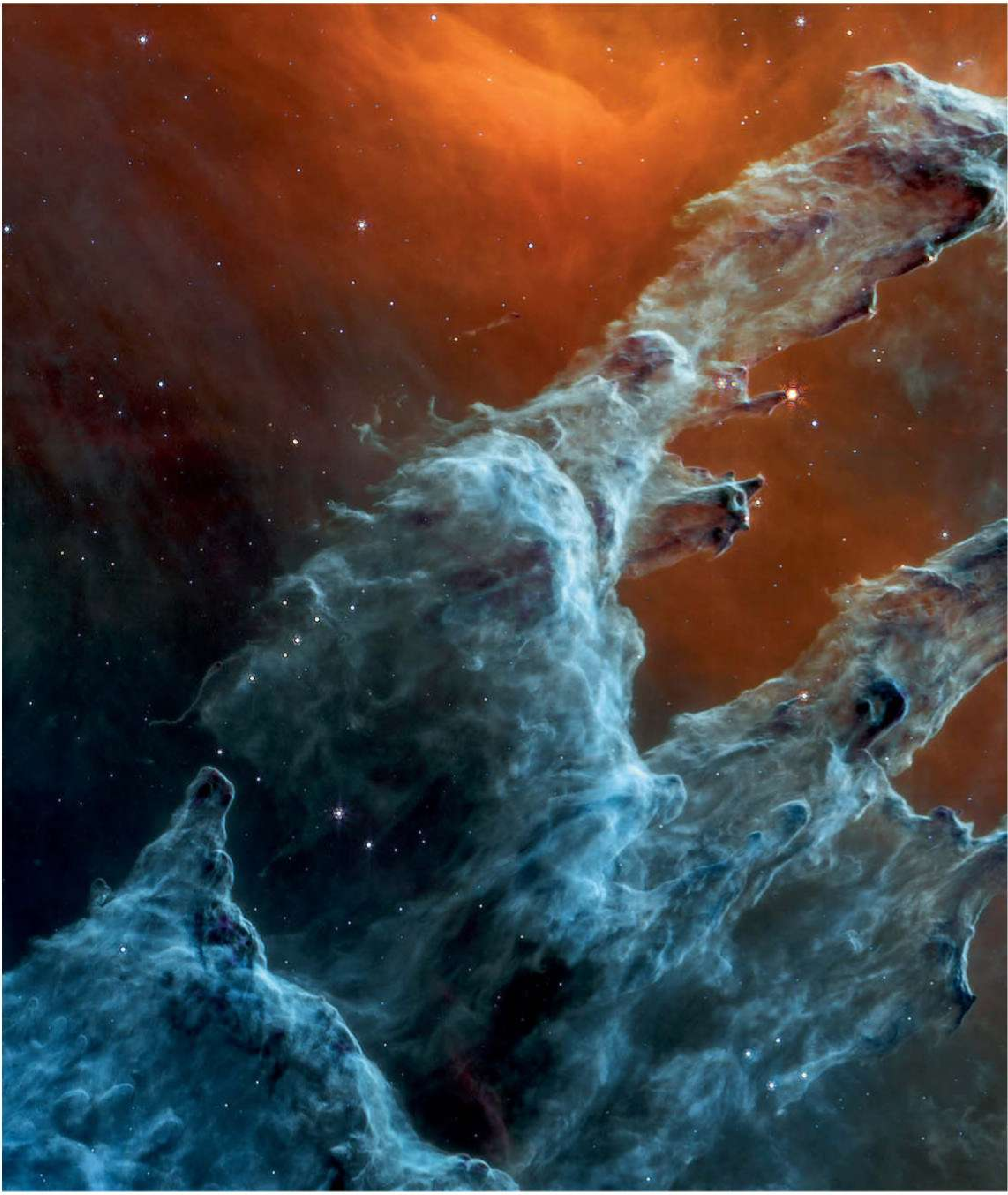
At the opposite end of the world, efforts to manage the Arctic's pressing issues, from wildfires to ice-free shipping lanes to thawing permafrost, became complicated by geopolitical events. All members of the diplomatic Arctic Council except Russia suspended participation in March following Russia's invasion of Ukraine. The war "has sucked all of the air out of any conversation regarding Arctic geopolitics or cooperation", says Scott Stephenson at the RAND Corporation, a global policy think tank.

> "Efforts to manage the Arctic's pressing issues have been complicated by geopolitical events"

Temperatures were rising in other ways, too. In September, warm and wet remnants of Hurricane Fiona brought record heat to Greenland and caused billions of tonnes of ice to melt in a "very bizarre" event, says Mark Serreze at the National Snow and Ice Data Center in Colorado. Faster melting is a trend that is set to continue in 2023. ▮

Icebergs float in Disko Bay, Ilulissat, western Greenland, on 28 June

ODD ANDERSEN/AFP VIA GETTY IMAGES



NASA, ESA, CSA, STSCI

Astronomy

Cosmic celebration

The James Webb Space Telescope delighted and thrilled us in its first year

Leah Crane

ASTRONOMERS began 2022 waiting with bated breath for the first images from the James Webb Space Telescope (JWST). It arrived at its orbital parking spot in January, then aligned its mirrors and tested its cameras.

There were 344 "single-point failures" – elements of the launch and deployment of the telescope that would have been catastrophic if they went wrong – and not a single one proved to be a problem.

NASA released the telescope's first fantastic images in July, showing the Carina Nebula, the Southern Ring Nebula, a group of galaxies called Stephan's Quintet, and the deepest image of the cosmos ever taken. Astronomers also showed off the spectrum of light shining through the atmosphere of an exoplanet called WASP-96b, which is a gas giant located about 1150 light years from Earth.

All of these have provided new insights, but the deep-field image (below) has been especially scientifically fruitful. Many of the faint galaxies it shows had never been seen before, and one of them was the most distant galaxy whose composition we had ever been able to measure.

While constructing and launching the telescope was extraordinarily difficult, taking pictures with it has proven relatively quick and easy.

"The previous record holder [for the deepest image of the cosmos], the Hubble Extreme Deep Field, was two weeks of continuous work with Hubble," said JWST scientist Jane Rigby during the image release event at NASA's Goddard Space Flight Center in Maryland. "With Webb, we took that image before breakfast… We're going to be doing discoveries like this every week."

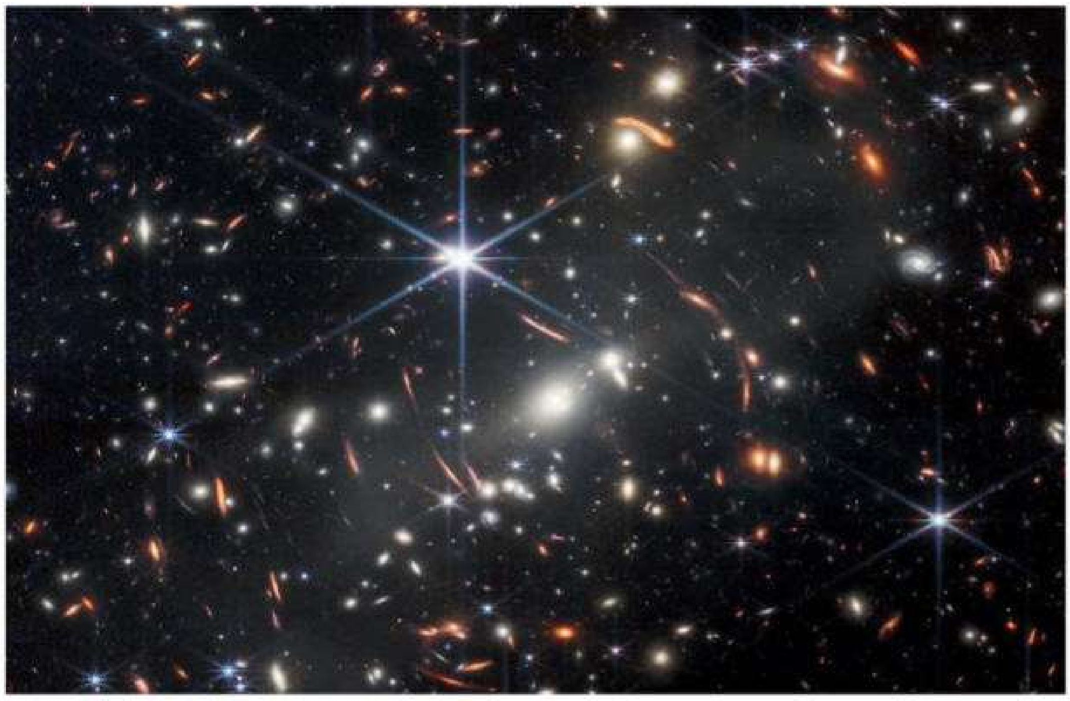
She wasn't exaggerating. After those pictures, the floodgates were open. JWST found the most distant galaxy ever, and then more that were even further away. It has now seen galaxies that could be so far away that they would break our models of galaxy formation and evolution, although it will take more time for their distance from us to be confirmed.

It observed galaxy pairs in the process of colliding, their gas slamming together and sparking bursts of star formation, and a galaxy with strange ring structures that formed when another galaxy blasted through its centre. Astronomers were even able to pinpoint the most distant individual star ever seen, almost 20 billion light years more distant than the runner-up, and began investigating what the first stars might have been made of.

The telescope took direct images of exoplanets, which is nearly impossible to do from Earth, and measured their atmospheres. There, it found strange clouds made of sand and spotted carbon dioxide in the atmosphere of an exoplanet for the first time. JWST even recreated the famous Hubble image of the Pillars of Creation (left). And with enough fuel for 25 years of observation or more, this wonderful observatory is just getting started. ▮

Left: The famous Pillars of Creation, as seen by JWST

Right: JWST's first deep-field image provides a look at the early universe



NASA, ESA, CSA, STSCI, NIRCAM

Technology

Fusion energy becomes a more feasible prospect

Matthew Sparkes

THERE is a joke that fusion power is 30 years away and always will be. But 2022 has seen records broken and hypotheses confirmed by experiments. The remaining hurdles are issues for engineers, not physicists, Lee Margetts at the University of Manchester, UK, told *New Scientist* earlier this year.

In February, the Joint European Torus reactor near Oxford in the UK sustained super-hot plasma for 5 seconds, producing a record 59 megajoules of energy. The hope is that ITER, a larger reactor being built in France, will build on this once it is running in 2025.

Another step forward came in the same month at the Swiss Federal Institute of Technology in Lausanne, where the TCV reactor ran for 2 seconds controlled by an artificial intelligence. Taming the hot plasma in a reactor is crucial, and DeepMind's AI shaped this in various ways, some of which may improve plasma stability.

In September, in South Korea, a further advance arrived, with a fusion reaction notching up a remarkable combination of duration and heat: 30 seconds at more than 100 million°C.

Even as *New Scientist* went to press, there were rumours of a net energy gain at the Lawrence Livermore National Laboratory in California – a first for a fusion reaction. It seems the question now isn't whether it will work, but who will get there first. ▮

> "It seems the question now isn't whether fusion will work, but who will get there first"

THOMAS COEX/AFP VIA GETTY IMAGES

The Guadiana river in Spain, which nearly vanished in August

Climate change

Rivers running dry

Extreme drought turned swathes of Europe to dust

Madeleine Cuff

THE crunch of leaves underfoot is usually associated with autumn. But this year, it was the soundtrack to summer strolls across Europe, as maximum temperature records fell and the continent suffered its worst drought in 500 years.

The dry weather pushed millions of trees into survival mode, with many shedding leaves to conserve water and energy.

Their bare branches were one of the most visible signs of a landscape in crisis during the long hot summer as rivers, reservoirs and underwater aquifers ran dry.

"It was very clear from just looking around the landscape that we were in a very serious situation," says Hannah Cloke at the University of Reading, UK.

The drought had been building for months after a dry winter and spring, but it was turbocharged by a series of fierce heatwaves over the summer, says Simon Parry at the UK Centre for Ecology & Hydrology. It was a "perfect storm of conditions", he says.

The crisis exposed the fragility of Europe's energy system, already weakened by Russia's war in Ukraine.

In France, nuclear power plants were forced to curtail their output as low river flows meant there wasn't enough water to cool their reactors. Water levels on the Rhine river dropped so far that ships loaded with commodities in Germany and the Netherlands, including coal and petrol, were unable to travel. Hydropower generation in Norway slowed, prompting the government to cut power exports.

16%

Possible fall in yield of key crops in Europe, such as maize, due to drought

Farmers saw crops wither. In Europe, yields of maize, soya beans and sunflower seeds were predicted to fall by between 12 and 16 per cent in 2022.

This was a crisis caused in large part by climate change, says Richard Allan, who is also at the University of Reading. "Warming due to human-caused climate change made this event much more extreme," he says. Climate attribution studies suggest that the drought was made at least 20 times more likely by global warming.

Parts of Africa, China and the US were also hit by drought, with China having the worst heatwave ever recorded anywhere.

However, that missing rainfall ends up somewhere, says Peter Gleick at the Pacific Institute in California. This year's devastating floods in countries including Australia and Pakistan are the "flip side" of the droughts, he says.

"The droughts and the extreme floods that we are seeing are tied together, are part and parcel of the broader challenge of climate change," says Gleick.

In the wake of a drought, it is critical that nature gets time to recover. But for Europe, this was the second severe drought in four years. "My grass has already recovered from this summer… but if I had a tree that survived it, that would take 10 years or more to get back to a normal state," says Niko Wanders at Utrecht University in the Netherlands. ▮

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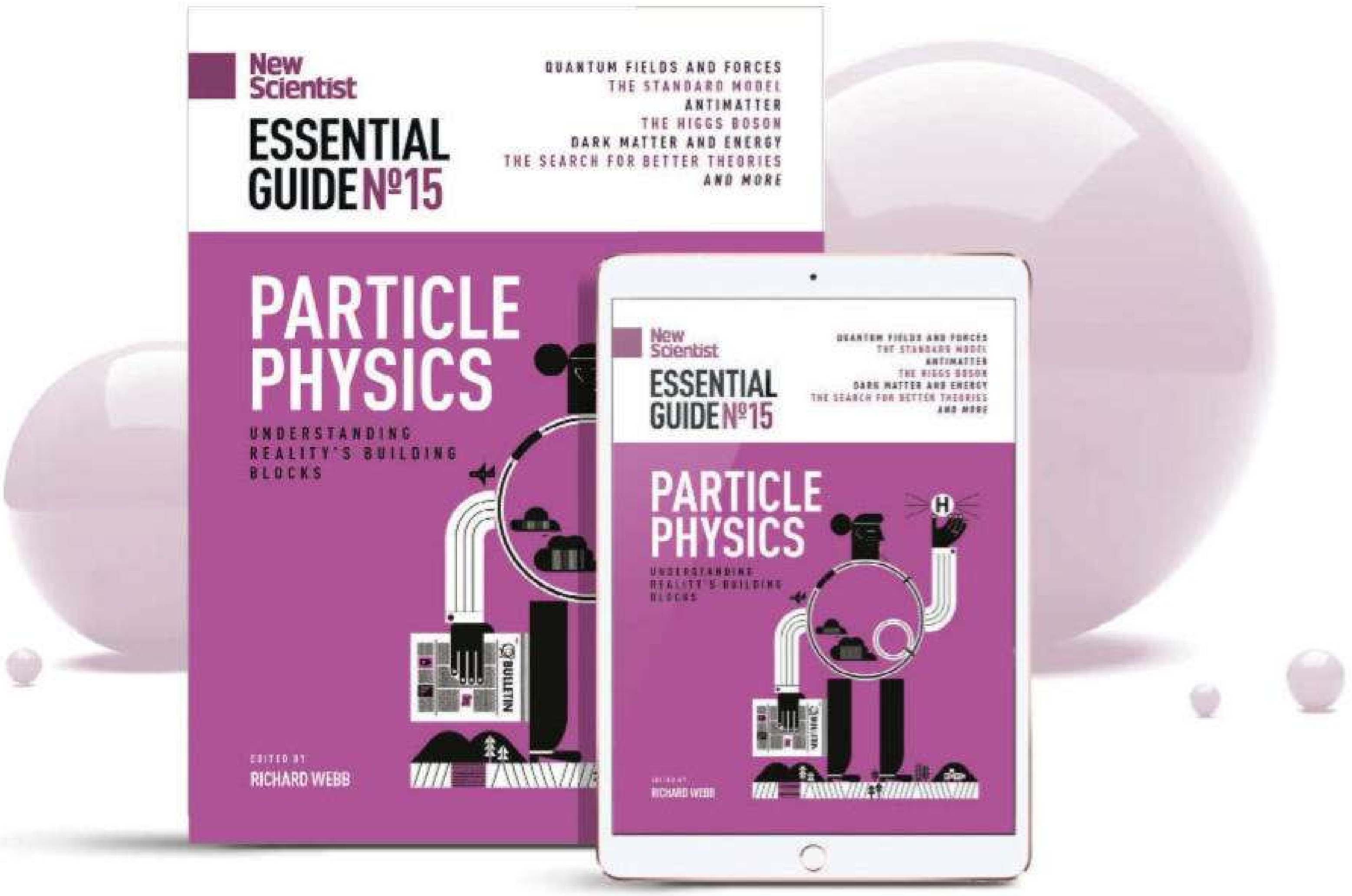

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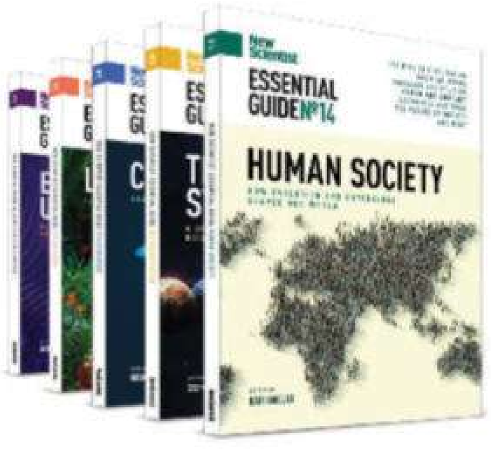

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Letters
Details of first language may be lost forever p34

Culture short story
An exclusive science-fiction story by Arkady Martine p36

Cosmic challenge
Can you crack our interlinked space-themed puzzles? p43

Aperture
A storm captured in full fury and a frozen Niagara Falls p46

Columnists

Life, death and wormholes

New Scientist's columnists examine 2022's tech failures, a controversial simulation, some good news about nature and its benefits to mental health

Annalee Newitz on why the tech apocalypse might be a good thing

IT HAS been an apocalyptic year for technology, but that doesn't mean we are heading for dystopia. In fact, the biggest tech failures of 2022 are actually an encouraging sign that many humans are still quite sensible despite everything.

As I discussed in my most recent column (10 December), Twitter appears to be imploding after new owner Elon Musk fired thousands of staff and allowed vaccine deniers and white supremacists back on the platform. For many of us, it seemed like a nightmarish harbinger of things to come online.

The immediate reaction of many advertisers and users was "get me the hell out of here". Twitter's advertisers fled; many will never return. With them went the site's biggest source of revenue. Then Musk's plan to recoup losses by charging users $8 per month for verified member status caused so many problems he walked the plan back within days. People may be visiting Twitter to watch it burn, but few are willing to pay for its continued existence. That gives me hope.

SIMONE ROTELLA

Meanwhile, FTX, one of the world's biggest cryptocurrency exchanges, was shown to be built on sand. It was a bullet into the head of blockchain hucksters. Banks and investors lost millions, and FTX owner Sam Bankman-Fried went from billionaire to broke overnight. As technologist Molly White has chronicled on her crypto-sceptic site Web3 Is Going Just Great, the so-called crypto revolution has made a few people rich – and bankrupted countless innocent investors who didn't understand what they were getting into. Lives have been ruined. The end of FTX means fewer people are now at risk of losing their money and there is greater awareness that crypto investments can be more like pyramid schemes than bridges to a brighter future. Score one for justice.

In news I find both hilarious and heartening, a recent report revealed that Amazon's creepy digital assistant Alexa has failed as a product. You know Alexa – it lives in a little device and responds to voice commands like "play a song by X-Ray Spex" or "tell me the mass of the sun". It also has well-documented surveillance features that are quite alarming, such as recording everything said nearby, even when the device appears to be off. Amazon was selling Alexa products at cost because the firm assumed that people would use them to buy lots of stuff from Amazon, allowing it to recoup its losses on sales of the device.

Apparently consumers were having none of that – at least, not the human ones. There is a very popular story of a parrot that managed to order ice cream and strawberries through Alexa. But for their part, humans mostly used their Alexa assistants to play music or answer questions. I will admit the main thing I used Alexa for was telling maths jokes. It has a surprising number of good ones! At any rate, my faith in humanity was restored when I read that nobody was using these things to buy more stuff from Amazon.

There was one piece of genuinely sad news in the tech industry this year. Many of the biggest tech companies, from Amazon to Meta, announced mass layoffs right before the holidays. When we focus on the rich and powerful men who own these companies, we often forget about the real casualties these billionaires leave in their wakes. People lost their livelihoods. Some of them are contractors who got no severance pay and are a month's salary away from living in their cars. If you know somebody who has been laid off or whose job has suddenly become more precarious, please do something nice for them this holiday season.

Farewell to Twitter, FTX and Alexa! Long live humanity! ▮

Graham Lawton on how nature can help with mental health

I WON'T mourn the passing of 2022. It has been an annus horribilis for me, my family and our friends. Clare, my life partner of nearly 30 years, wife for 24 of them and mother of my three children, ended her own life in August after enduring a chronic pain syndrome for the best part of a year. I became her carer as her pain spiralled into an abyss of torture. I tried everything I could to save her life, but I failed.

My mental health deteriorated when I was caring for her, and cratered when she died. I take antidepressants, which at least allow me to get out of bed in the morning. But what I find also helps me cope is spending time in nature. We don't have a lot of that in the part of London where I live, but there are pockets.

Last month, I had the opportunity to spend time in some properly biodiverse nature. I was invited to visit a project in the Queen Elizabeth National Park in Uganda. The place is dripping with nature. I saw elephants, hippos, lions, hyenas, leopards, crocodiles and endlessly beautiful birds. For somebody who lives in a nature-depleted country, the experience of being in proper wildness is awesome, and I mean that in the true sense of the word. Clare would have been awed by it too.

The mental health benefits I got were immeasurable. I felt a lightness and joy that I hadn't experienced for many months. Returning to my empty house brought that crashing down, but I am sure my time in Uganda will help my recovery in the long term.

This isn't just anecdotal musings from a grieving husband. Research backs up the fact that spending time in nature is good for mental health. That is one reason why the wanton destruction of nature in the name of unlimited profits is an act of self-harm: short-termist, greedy and ultimately suicidal. I don't use that word casually.

Many Western countries, the UK especially, have already destroyed most of their nature. Even when we go to supposedly wild places like the Lake District, what we are experiencing is a human-created landscape once covered in trees, but now covered in sheep.

One argument for preserving nature is that it provides us with ecosystem services such as clean air. But one service that tends to be neglected is the benefit to our mental well-being. A 2019 report by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services briefly mentions "inspiration" and "psychological experiences", but they are near the bottom of its list of benefits.

In April, I went to the launch of the British Ecological Society's report on the UK's nature recovery. I asked a question about the wisdom of investing in the UK's biodiversity given that we don't have much of it. Wouldn't the money be better spent protecting near-pristine ecosystems?

The answer put me straight. "I think we've all recognised over the last few years how important green spaces are locally for health and well-being," said report co-author Jane Hill at the University of York, UK. "Yes, we've got less biodiversity than a tropical location, but it's still hugely important to people's well-being."

Clare is buried in a woodland plot in a London cemetery. It is a beautiful place, apart from the fact she is there. I visit often, talk to her and enjoy the magnificent trees. I won't mourn 2022, but I will mourn her for the rest of my life. ▮

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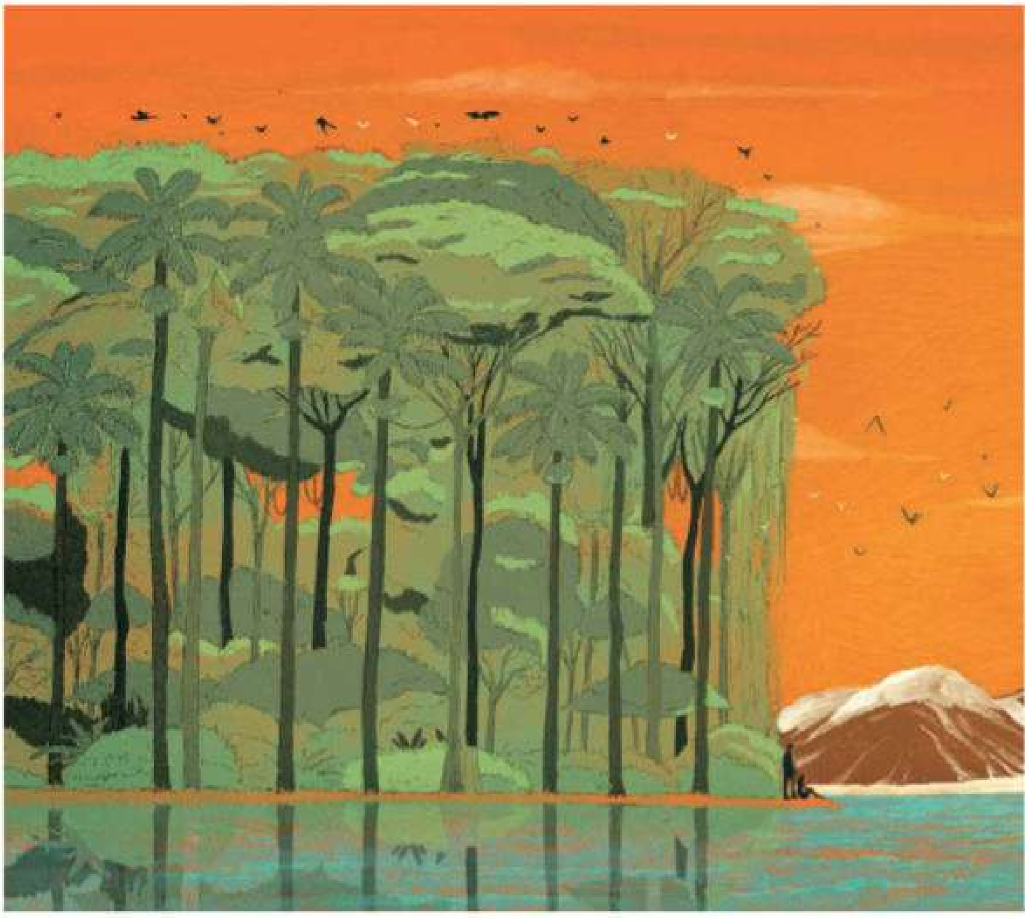

Chanda Prescod-Weinstein on quantum wormhole drama

THIS was a huge year for me professionally, and also one of the hardest years of my life personally. I won four awards for science writing, including three for my book *The Disordered Cosmos*. But my dear Uncle George Preudhomme passed away, and saying goodbye was extremely difficult. Death is, unsurprisingly, often hard because we want people to go on forever. And perhaps the strangest thing about 2022 is that it feels like we are beginning to confront a kind of real-life science fiction where that will become possible.

Just a week after Uncle George's funeral, ChatGPT became available for use. Those behind it, at Open AI, describe it as "a conversational AI system that listens, learns, and challenges". Effectively, it is an artificial intelligence that anyone can converse with, just like a text message exchange or an instant messenger. The discussions about this on social media brought to mind a short story by Alexander Weinstein (no relation, as far as I know), *The Year of Nostalgia*. In it, a man who recently lost his wife provides all records of her to a service that creates an artificial, holographic version of her that he can talk to. Effectively, she is a ChatGPT that is trained on the words of a dead woman.

Weinstein's characters grapple with whether the hologram is equivalent to the real thing. It should be obvious the answer is "no", but the same week that ChatGPT opened for public use, a somewhat-related controversy roiled the science communications community. The California

"Is our constantly evolving relationship with tech shifting our sensibilities about what is real?"

Institute of Technology put out a press release stating that Maria Spiropulu and her colleagues had, for the first time, used a quantum computer to simulate a wormhole, a hypothetical structure that connects distant points in space-time.

To cover this story, various publications produced headlines like this one – subsequently changed – from *Quanta Magazine*, “Physicists create a wormhole using a quantum computer”. Yet the very second sentence of the press release opens: “The experiment has not created an actual wormhole…” Drama ensued on Twitter.

Scientists, myself included, were annoyed. There is a difference between a simulation and the real thing and this seems obvious when we talk about simulating a dead person versus someone actually being alive. In our daily work, my group runs simulations of dark matter candidates with various properties and in different astrophysical scenarios to get a sense of how that dark matter would behave if it were real. At no point do we conclude that we have made real, physically tangible dark matter in the process.

The argument that this wormhole scenario is different comes down to the quantum nature of the simulation machine. Theoretical physicists who work on quantum gravity have proposed that specific types of quantum systems are connected to wormholes – in a simplified space-time that is different from the one we live in. As a result, some would argue that the quantum phenomenon is identical to a wormhole. I think this is the wrong take – it is still just a simulation – and experts on quantum computing and quantum gravity seem to largely agree with me.

But the fact that there was a debate at all is intriguing. Is our constantly evolving relationship with technology shifting our sensibilities about what is real? I think 2023 will provide interesting data about the emerging answer to this question. As Weinstein’s story shows, this has implications well beyond physics. ▮

Penny Sarchet runs through some of her natural highs of the year

BEING a wildlife enthusiast at this point of the Anthropocene can feel like desperately trying to enjoy the very best of planet Earth while it is in the process of rapidly vanishing, a feeling that intensified for me this year. In October, the 2022 Living Planet Index, an analysis of 5230 species of vertebrates, suggested that populations of mammals, birds, reptiles, amphibians and fish have, on average, declined by 69 per cent since 1970. When enjoying spring birdsong, for example, it is hard not to feel sad for how much louder and more widespread it was not that long ago.

But there is still much to discover, marvel at and love in the natural world, even as habitat loss, climate change, overexploitation and invasive species continue to damage it. So, at this special time of year, let’s give ourselves a brief pause from grief to celebrate some of the year’s good news.

While vast numbers of species are currently under threat, the fortunes of some have turned around. In July, we heard that southern fin whales now appear to be doing well in the Antarctic, following a 1976 ban on hunting these animals in the southern hemisphere. This was followed by the news that Saiga antelopes have rebounded on the Kazakhstan steppe, after nearly being wiped out by hunting and disease.

Many new-to-science species were described in 2022. One was a water lily collected in Bolivia in 2016 that was this year confirmed as a distinct species, *Victoria boliviana*, and announced as the largest-known giant water lily in the world. And I enjoyed reporting on *Rhinella unapensis*, a toad discovered on a campus of the National University of the Peruvian Amazon by Rommel Rojas Zamora. He told me that, in the Amazon, “one can literally step out from one’s house and discover a new species”.

There were rediscoveries too. In Colombia, the Santa Marta sabrewing – a type of hummingbird – was officially spotted for the first time in 12 years, while on an island off Papua New Guinea, the black-naped pheasant pigeon was documented for the first time in 140 years.

But I think the most inspiring article I read this year was about how a community-led conservation programme in Guatemala has set two decades of deforestation in the Maya Biosphere Reserve in reverse. The area had suffered great losses due to cattle ranchers and drug traffickers. To halt this, the programme granted local communities control of the forest, on the proviso that they conserve it, and researchers helped these communities to find ways to live off these forests sustainably, producing goods like allspice and gum with minimal felling of trees.

> **“There is still much to discover and marvel at in nature, even as human activities continue to damage it”**

The project still has a long way to go, but not only has it achieved the remarkable feat of switching the forest from net loss into net growth, researchers say the lessons learned there can be applied in other tropical forests around the world, too.

That’s the kind of hope I want to take into the new year – one that is grounded in the reality of the huge damage we are causing the natural world, but that knows it is possible to regrow forests and restore whale populations. There is still everything to fight for. ▮

Editor's pick

Details of first language may be lost forever

26 November, p 36

From Michael Swan, Chilton, Oxfordshire, UK

Your article on the history of European and other languages was interesting and informative. As Andrea Valentino reports, linguistic and genetic research in combination may push back our knowledge to 12,000 BC or even earlier, and this might tell us something about a possible language from which apparently unrelated linguistic groups (Indo-European, Uralic, Turkic and others) have descended.

However, the suggestion that we may, therefore, be coming closer to uncovering the "deep roots of language" and establishing the nature of the "mother tongue" that was the ancestor of all languages, is quite unrealistic.

Language has existed for perhaps 150,000 years. For around 90 per cent of human history, languages have developed, been displaced, split, displaced other languages and become extinct. Very nearly all the languages ever spoken have certainly disappeared without trace.

Even if there were a single ancestral "mother tongue" – and this isn't certain, as language may have developed more than once in different populations – all we can know of its nature is that it shared the structural features that all languages must have in order to function. More specific information is, sadly, irrecoverable.

Reptile talk is no surprise to owners of pet turtles

29 October, p 12

From Virginia Trimble, Irvine, California, US

You report on a study revealing that turtles vocalise. However, anyone who has had the privilege of a Testudinidae roommate won't be surprised. They will probably remember approaching his or her bowl at dinner time, seeing a head rise up above the water, mouth open, and hearing a soft little peep.

Could this be the answer to cosmic constants puzzle?

19 November, p 46

From Geoff Sharman, Winchester, Hampshire, UK

In your interview with Roger Penrose, he points out that "nobody knows where the fundamental constants of nature come from".

Neither an infinitely numerous multiverse nor an infinitely repeating cyclic universe seems to offer plausible or attractive answers to me. But perhaps there was some evolutionary process in the early universe, which we don't yet understand, by which many of the possible combinations of constant values were tried out rapidly – since a lot of them would lead to immediate collapse – until a stable combination was arrived at, resulting in the universe we see. In other words, ours is the only possible universe.

How to get around the car recharging problem

26 November, p 25

From Sue Cannon, Lawson, New South Wales, Australia

After reading Kathryn Harkup's vision for an electric vehicle future, I wonder if it isn't too late to change direction in how we handle the problem of rapidly recharging electric transport. Perhaps we can return to an idea used on London buses more than a century ago.

If there were a small number of standard conformations of car batteries, then, instead of long, frustrated queues of holiday traffic waiting for a half-hour session at a public recharging station, things could be easier. This is how I imagine it. A car pauses at the re-batt station. The type and position of its battery has been read, and the spent one is swiftly removed and then replaced robotically. The driver taps their bank card and they are on their way.

Large companies would be responsible for making, maintaining and recycling these batteries, which would be charged with surplus renewable energy.

For geothermal, the Tube offers a source of heat

29 October, p 16

From John Bainbridge, Ottawa, Ontario, Canada

I can't help feeling that heating the UK with geothermal energy is just another misguided, silver-bullet solution. Your article reports there are (maybe) 100 years of energy that could be harvested. That doesn't sound like that much.

After 100 years, we would have to tackle the ecological effects of geothermal energy – because there are bound to be some. Maybe a better use of geothermal technology would be to extract the heat that has been dumped into the ground over the past century by London's Tube trains.

In praise of Chanda's stance on JWST name

Letters, 12 November

From Gabriel Carlyle, St Leonards, East Sussex, UK

Simon Robinson objects to Chanda Prescod-Weinstein's proposal that the James Webb Space Telescope (JWST) be renamed in honour of Harriet Tubman, writing: "Let us remember past scientists, technicians and engineers for their contributions to their fields, without seeking to judge them because they lived at a time when social attitudes were different."

But Webb wasn't a scientist, technician or engineer: he was a career civil servant and head of NASA at the time of a federal policy of purging LGBT individuals from the agency's workforce.

As Prescod-Weinstein has noted in her writing on this issue: "The time for lionizing leaders who acquiesced in a history of harm is over. We should name telescopes out of love for those who came before us and led the way to freedom – and out of love for those who are coming up after."

Climate action will only come with mass suffering

Letters, 3 December

From Denis Watkins, St Just in Roseland, Cornwall, UK

Lloyd Timberlake accurately summarises why we "will not and cannot manage" the challenge of climate change: "We won't make major sacrifices for future generations." We continue, as with COP27, to pretend to act in earnest.

Additionally, most of us in wealthier countries can still deceive ourselves by clinging to the comforts of the lives we have known. And, as is seen by the reaction of the UK government, any climate protests that cause inconvenience will be dealt with increasingly harshly. Also, different governments act in different ways, and some may be influenced by people who deny the reality of climate change.

The question remains: can we change? The only way, it seems to me, will be when suffering is so widespread that the populations of various countries insist on a different type of leader with much changed and more collaborative agendas.

The future seems bleak, but we must keep acknowledging the problem and demanding such change. ▮

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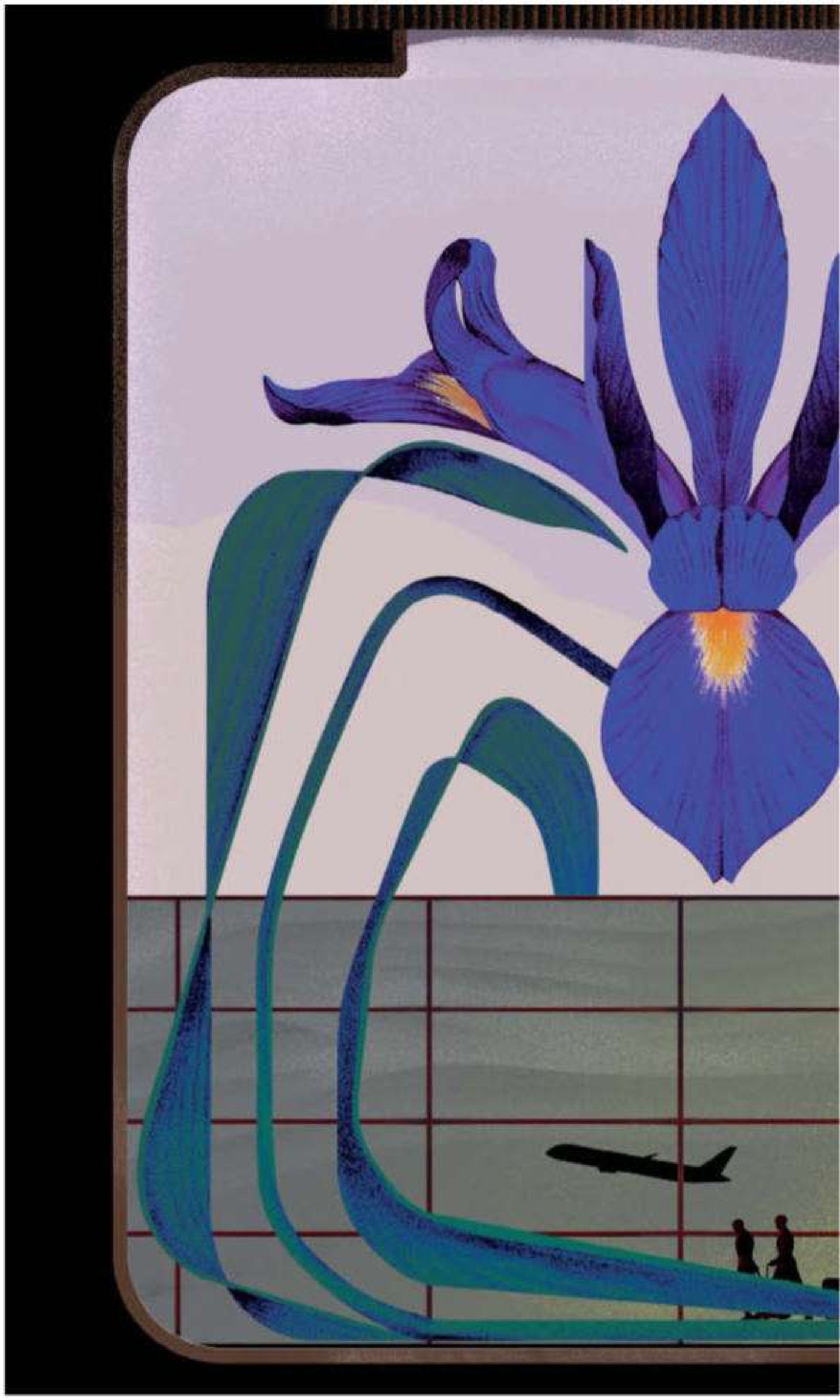
BIG IDEAS IN PHYSICS SERIES
JOHN C MATHER

Orris

In a future where climate change has devastated Florence's iris fields, a perfumer makes a hard choice, in this short story by **Arkady Martine**


BEKOLOGIC

Elena could give the lecture half-asleep. She'd done it more than once: earbuds shoved in haphazard in the dark and micbead balanced on her sternum, the rest of her cocooned in 30 pounds of weighted blanket. Warm, serene and bodiless. When she needed to do an onboarding for someone in a time zone radically askew to her circadians, she'd even skip VR. The lecture didn't need an image, just a voice. In Elena's opinion, it worked better with just a voice. She had the data analytics to prove it, and those data analytics earned her the top end of her salary band.

Perfume chemistry is dependent on the interaction between a precision-crafted molecular architecture of volatile compounds – the perfume itself – and any number of individual human skins, Elena would say, and it didn't particularly matter who she was saying it to: they were already inhaling their own pre-prepared mix of terpenes and coumarins, carvone and limonene, all suspended in a high-oxygen room air mix suitable for closed-envelope office buildings. Elena had smelled it herself. All professional noses tried their own designs; all company noses knew the proprietary formulas down to the molecule. The standard scent for corporate installations was mostly spearmint and shiso leaf. It smelled like clear thinking and productive energy, and it was next to impossible to notice the proprietary mix of inhaled stimulants that her company added to particular rooms, when a particular person needed them.

Human skins were the variable factor, the uncontrollable random draw – the heat and the oil of them, the particular variations in hormones, nutritional factors, age, humidity. The skins, Elena often thought, were where the plan encountered the enemy. And no plan survived the encounter with the enemy, according to both proverb and companyspeak fable.

Or, at least: no plan survived unchanged.

The vial she wore on a chain around her neck was blood-heat warm. If she unstoppered it, the scent of the waxy substance inside would be different from how it would smell in a lab or a distilling facility. Different, even, than it would smell when it was first ground and pulped from rhizome. Heat did that. Proximity to her own skin oils – not even touch, merely *proximity* – made those infinitesimal alterations. Elena rarely unstoppered her vial. Wearing this much orris root – the concentrated powder of the rhizome of the bearded iris, *Iris pallida*, grown in the sandy soils outside of Florence, aged for five years underground and dried for three more before processing – well. It was ostentatious, even for a professional nose. Especially because all of that growing and harvesting and waiting had been done in the first half of the century, before the fields outside of Florence had ceased to produce rhizomes with their traditional characteristic depth of scent.

Elena had been wearing her orris-root vial for more than a decade. It was ubiquitous to her, as expected as a uniform.

She'd worn it to the airport, just this morning. Walked right through the security scanners, shoeless and sunglasses-less, squinting unhappily against the fluorescent lights. The airport made her miserable, even if her

Bio
Arkady Martine

Arkady Martine is the author of the Hugo-winning *Teixcalaan* series, the novella *Rose/House*, a multitude of short stories and various other sci-fi, fantasy and horror works. She is also AnnaLinden Weller, a Byzantinist, climate and energy policy analyst and city planner. She isn't bored.

reasons for spending a flight credit were as legitimate as spending flight credits for anything less than family medical emergencies could be: she hadn't taken a vacation in six years. She'd saved up. She was on her way to the high canyons and the orchards of lower Colorado and northern New Mexico, to go – oh, hiking. Sightseeing. A place she had never been, she'd told her boss when she'd applied for the time off. Somewhere alien and new.

The airport was all noise and light, announcements over the loudspeaker. She'd put her sunglasses back on straight after security and decided not to care that she looked like someone who was hiding an unfortunate hangover or a more-unfortunate black eye. It didn't help enough. Most of the light and all of the noise still came right through. Her flight was boarding in 38 minutes. Airports smelled of ozone and sweat. People and high-potency aerosol disinfectants. Elena wished profoundly that she could be a voice giving a lecture, the same lecture over again, safe in her own dark apartment with nothing moving aside from the unfolding patterns of perfume.

She could turn around now. It would be understandable. The people on the other side of the flight wouldn't be any worse off than they were already.

She was grinding her teeth, slow pressure in her jaw. Deliberately, like she had practiced under the tutelage of two therapists and a dentist, she relaxed it.

#

A perfume can be created in a lab, entirely synthetic. Perfume chemistry is not the best-paid use of an organic chemistry degree, but it is a prestigious one: complex, a skill with its own profundity. Some of the best historical perfumes have been based in synthetics: Shalimar was built around vanillin, Chanel No. 5 around a series of synthetic aldehydes. Ambroxan is the secret heart of Dior's Bois d'Argent.

Most of the perfumes Elena had ever built were *entirely* synthetic. The plant and animal-derived versions of their components were either vanishingly rare, protected from harvest by international law, cost-ineffective at scale, or – like the orris root butter she wore around her neck – born from a terroir that has been transformed beyond its previous capabilities to imbue a particular scent. Heat changes the chemical composition of anything, not only olfactory molecules. Heat, and drought, change the chemical composition of soils.

Inside that vial, enrobed and invisible inside the pale beige wax of the orris root butter, were nine arils: the seeds of a bearded iris grown before that change in climate and season had made its permanent alteration.

#

Elena found the airplane itself comforting after the chaos of the airport. She had tucked herself against the window in her seat two-thirds of the way back towards the galleys, well behind the wings, and was fully prepared not to move at all until they had landed again. Nothing would happen; the worst alteration in her circumstances would be clear-air turbulence. She liked it. The country unrolling under her was grey-green with early spring.

She didn't consider herself a thief. The iris arils were a curiosity, not a monetisable product belonging all proprietary to her company. She had never used orris in a productivity mix in her entire term of employment – and she'd never used it when she'd worked on the sleep-and-relaxation side of the shop either. It was too expensive. In the 20th century and the early 21st, the butter had still been the best fixative base for *wearable* perfume, no matter the price – but it wasn't the early part of the 21st century by two decades. Two decades if a person was being generous. Nine original-terroir arils – not even the rhizome! Only the thing that could become a rhizome, in half a decade! – were like coins lost in couch cushions.

She was very aware that she was lying to herself.

#

It had started with a series of peer-reviewed soil science studies, emailed to her work account anonymously. Elena had deleted them, and relegated the sending IP to junk. They kept appearing anyway; the same few › at first, mostly in pre-print, and then confirmations of the findings a few months later, under the auspices of more reputable journals.

(Of course she'd read them, before she deleted them.

She'd been *fascinated*. Someone was trying to communicate with her, however surreptitiously and sideways, and they had *data*. She'd put the charts and data sets from the soil studies up in a private VR environment, sensibly isolated from the rest of her system, and let them spin around her like a cacophony of stars.)

The initial set described the ill effects of soil aridification on perfume components, specifically orris, *particularly* in the north of Italy, alternately scorched by heat and parched by unusual drought. The set that followed were more theoretical. They hinted at rewilding, at *alt-wilding*, a practice of locating climate-alikes, sibling locations disparate in time and geography – and introducing the extirpated or near-extirpated natives of the one to the other. Elena knew alt-wilding: it was an activist dream, the sort of project uninformed kids or aged-out wellness influencers trying to go climate-legit went for. It was harder to do than it looked. It wasn't realistic.

"Elena knew alt-wilding: it was an activist dream, the sort of project uninformed kids went for"

It wasn't realistic, except when it worked. The people in the climate-alike had to know the ground. Had to know the earth and water and cyclical movement of it. Tenth-generation agriculturalists, or agrovoltaic herders, or Indigenous groups, or the saner descendants of prepper enclaves – two or more of the above were better, if you were betting –

The last set of papers came to her personal email. Elena had always thought she had decent cybersecurity protocols. Her personal email was a throwaway, and she changed it every couple of months. Until the last set of papers came in, as jarring as a static shock, it had been entirely inviolate to everyone she knew through work. She'd believed that what she did on God's own internet was her own business, and the business of ad trackers who were interested in whatever it was that she made her business; what she did while she was a corporate nose was another thing entirely, and the two ought never to have collided. And yet. Whoever wanted her to be thinking about alt-wilding, thinking about possibilities, whoever had been *stalking* her with research papers and the sketches of ideas, like the skeletal base notes of a new perfume: they were here, they were so very close, and she (in the safety and dark of her own room), looking at the inbox she used for social media and early-access film festival reviews and missives from her therapist and her university best friends –

And yet.

There they were: two meticulous research articles, insinuating that the terroir of the Upper Pecos and lower Colorado displayed – now, not as it would have been a century

ago, but *now* – the same soil characteristics that had grown the rhizome outside Florence, before it had become only a host for flowers and not a host for scents. Two research articles, and an unsigned email from a burner address.

It only had one line. That line was: *you know how many iris seeds your lab has?*

She'd stared at it for three days before she answered.

Yes.

#

If she wanted, she could simply not leave the airport. The ticketing desks were only a floor above the baggage claim, and it wasn't like she didn't have money, and even after handing over one round-trip flight credit she still had the other five years of flight credits from not travelling – she never travelled! – to burn. She could buy a ticket to anywhere. Including her own city, with her own apartment, and all its quiet, dark rooms where nothing ever happened and she hadn't ever (plausible deniability, Elena) done anything illegal that was 100 per cent her own fault.

She could turn around and no one would ever have any reason to suspect her because she wouldn't have done anything to suspect. She could even return the arils, though it wasn't really worth the risk: there were at least 60 more of them in the seedbank vault, and no one was going to use them for something so prohibitively expensive as growing iris rhizome anyway. It might be years before they got counted. Decades.

She was stalling.

She hadn't come halfway across the country to be a coward.

She'd like to be a coward. The strap of her carry-on bag dug into the side of her shoulder and felt like it weighed 1000 pounds. There were loud kids goofing off on the baggage carousel, and louder high-pitched buzzes from the carousel itself whenever its motion sensors noticed they were goofing off on it. Outside there was a man – probably a man, the name had been a little ambiguous and he hadn't included pronouns in his signature block in any of the emails they'd exchanged – holding a sign with her name on it, and he was going to drive her up to an orchard farmstead on roads she'd never seen and when she got there she was going to commit industrial espionage.

For the sake of a possibility. For the sake of – if it *worked* –

Elena walked out of the baggage claim into the dry-sweet mountain air (piñon juniper, sagebrush, a thinness she thought of as *oxygen* and was in fact the absence thereof –), and looked for her name.

#

Yes, Elena had written, and two weeks later she had seen holophotos of the orchard. Her decrypter spat out a pair of them and spun her a VRscape to look them over in detail. The first: the orchard as it had been when the iris fields outside Florence were full of nodding, bearded flowers, extravagantly purple – it had been apples, then, and the occasional peach when there was enough water for a decent crop. And the second: the orchard now, the sandy semi-arid soil, the pH readings, the average temperature and rainfall. The fruit: apricots. Grapes.

> **"She wanted to know what she'd lost before she'd ever had a chance to know she was losing it"**

Help us prove it, her contact wrote. *Not everything lost is lost always*.

Elena had never, not once in her professional life, built a perfume out of a root that came out of the earth. That was made of the memory and breath of a place.

It wasn't that the synthetics were worse. The synthetics were art. Even when she made performance-enhancers and productivity scents, the synthetics in her lab were art and she was going to go home when this was over and make more of them, for as long as anyone would let her.

It was that she wanted to know what she'd lost before she'd ever had a chance to know she was losing it.

Halfway up the winding mountain road, staring unabashed at the geology unfolding out the window of the electric pickup, Elena unlooped her vial of orris butter from her neck and held it tight in her palm. Heating it. Altering it with her own warmth.

Getting ready to break it open on the earth. ▮

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Driving innovation and championing early and diverse talent in science

How AstraZeneca is aspiring to deliver transformative breakthroughs by developing scientific talent from across the globe

At AstraZeneca, our R&D approach is evolving from symptom control to disease modification, focusing on earlier and smarter interventions to improve patient outcomes across some of the world's most complex diseases. To deliver cutting-edge medical advancement, we need creative and different ways of thinking with help from diverse talent across the globe. Our early talent focus includes welcoming those with different skills, backgrounds, experiences and perspectives to our organisation to build an inclusive culture that drives innovation.

Science is a global team sport

Uncertainty around long-term career prospects, lack of effective mentorship and significant financial pressures are having a detrimental impact on postdoctoral applications and scientific exploration. Earlier this year we launched the AstraZeneca R&D Postdoctoral Challenge: an opportunity to support early talent while looking to drive R&D productivity, promote diversity of thought and stimulate research opportunities across the globe.

"The events of the past two years clearly show the need to push the boundaries of medical science has never been more urgent," said Prof Sir Menelas Pangalos, Executive Vice President, BioPharmaceuticals R&D, AstraZeneca. "Rapid progress in disease understanding, as well as scientific and technological advances are genuinely changing our expectations of what is possible. We were delighted to launch the R&D Postdoctoral Challenge to support the next generation of science leaders and help them translate their ideas into meaningful benefits for patients."

Unlike typical industry postdoctoral programmes where research projects are pre-defined, the R&D Postdoctoral Challenge encouraged autonomy and innovation, inviting candidates to propose their own research ideas and hypotheses that could contribute to tackling some of the world's most complex diseases.

The whole scientific canvas of AstraZeneca was open for exploration, with proposals sought across the breadth of our therapy areas and novel scientific approaches. Importantly geographic location was no barrier to entry; the programme was designed to embrace international collaboration by providing opportunities to scientists regardless of their location.

The AstraZeneca R&D Postdoctoral Challenge 2022

Final year MD or PhD students and postdoctoral researchers from around the world were invited to propose their own innovative ideas to accelerate drug discovery and development. Following our call for entries, we received over 120 submissions from nearly 40 countries that were narrowed down to a final six who were invited to Gothenburg to present to the judges on 19th October 2022.

Our six finalists represented a truly global team of scientists, hailing from the United Kingdom, Northern Ireland and Portugal to the United Arab Emirates and South Africa. From PhD students, postdoctoral research associates, postdoctoral fellows and project scientists, our finalists presented pioneering projects across a range of therapy areas. Among their proposals, we heard about their goals to help accelerate drug discovery and development for cardiac regeneration, heart failure, autoimmune disease and metabolic disorders. The innovative science presented served as a reminder not just of the need to take inspiration from as many people as possible, but also of the vital importance of collaboration within the scientific community.

Indeed, the science presented was so strong that all six finalists were awarded fully funded postdoctoral research positions at one of our strategic R&D centres.

Congratulations to the winners!

R&D
Postdoctoral Challenge

AstraZeneca

Meet the AstraZeneca R&D Postdoctoral Challenge Winners

- **Dr. Ana Filipa Dias Louro**

  Postdoctoral Researcher at the Instituto de Biologia Experimental e Tecnológica (iBET), Portugal

  Proposal title: Advancing extracellular vesicle-based therapies for cardiac regeneration

- **Cátia Alexandra Marques Bonito Ferreira**

  PhD Student at the Department of Chemistry and Biochemistry, University of Porto, Portugal

  Proposal title: Designing "first-in-class" pharmacological chaperones for rare metabolic disorders

- **Dr. Gonçalo Emanuel Duarte Rosas da Silva**

  Project Scientist at Aramune Technologies Ltd., Northern Ireland

  Proposal title: Characterisation of the cardiomyocyte surface proteome for the development of targeted therapies for heart failure

- **Dr. Rakhee K. Ramakrishnan**

  Postdoctoral Research Associate at the Research Institute for Medical and Health Sciences, University of Sharjah, United Arab Emirates

  Proposal title: Microbiome-based therapeutics for asthma

- **Dr. Patience Chihomvu**

  Postdoctoral Fellow, University of the Witwatersrand Medical School, South Africa

  Proposal title: Characterisation of anti-inflammatory properties of Lippia javanica Lippia javanica

- **Dr. Mark Waterhouse**

  Postdoctoral Research Associate at the Department of Pharmacology, University of Cambridge, UK

  Proposal title: Generating an Fcγ Receptor (FcγR) degrader toolbox to target FcγRs in autoimmune disease

Being part of AstraZeneca's postdoctoral community means working alongside leading university and industry professionals and our six finalists, now winners, will all have the opportunity to translate their ideas into reality while working at the forefront of scientific exploration.

Our culture enables people to work seamlessly and inclusively together, where all doors are open, talent and diversity are celebrated, and every voice is heard. It's by sustaining this culture that we are able to help unlock the power of what science can do.

Open Innovation

AstraZeneca is committed to accelerating research and science through Open Innovation, learn more about other collaboration opportunities, and sign up to receive details about the next R&D Postdoctoral Challenge at **https://openinnovation.astrazeneca.com**

Our next Open Innovation collaboration opportunity closes on 31st December 2022, if you are an innovator with a novel solution to global sustainability challenges, we want to hear from you! **www.openinnovation.astrazeneca.com/cosolve/cosolve-sustainability**

To stay up to date on the latest research from AstraZeneca, you can sign up to receive emails from What Science Can Do **www.astrazeneca.com/what-science-can-do**

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New Scientist
Newsletter

Launchpad

Voyage across the galaxy and beyond with our free weekly space newsletter.

We have entered a new golden age of astronomy. Let our resident space expert Leah Crane fill you in on all the very latest news about our exploration of the solar system and the fascinating insights into distant stars and worlds being revealed by bigger and better telescopes.

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A CHALLENGE OF COSMIC PROPORTIONS

This year has been a big one for space, with the launch of the James Webb Space Telescope and all the amazing images and discoveries it has brought us. In celebration, *New Scientist* and Charlie Wheeler at Ultimate Quest offer you a set of diabolically difficult space-themed puzzles spread over the next three pages.

Rather than solving them in number order, **the answer to each puzzle will direct you to another** one of the puzzles.

There are 10 steps in this journey. You will visit some puzzles more than once. Keep track of the number of the puzzles you visit here.

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

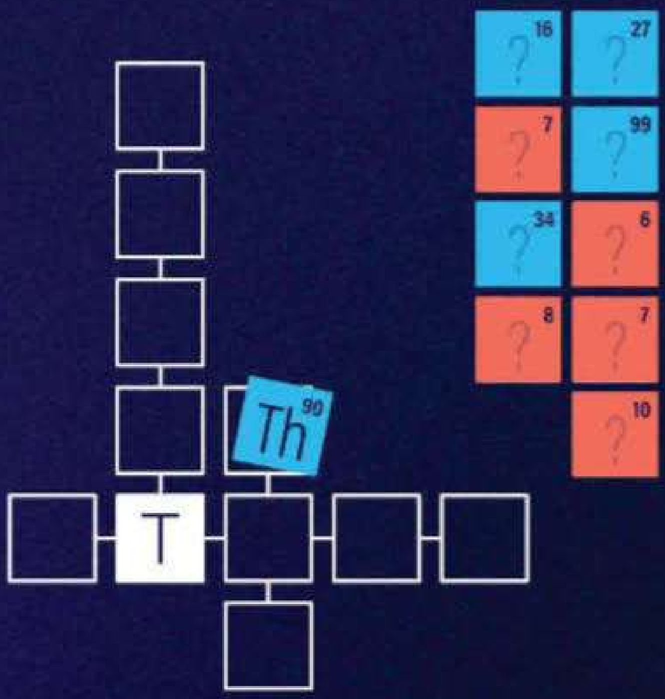
When you reach the end of the game, you will end up with a cryptic hint to **the overall answer, which you can record here!**

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

"a TV series"

Begin at Puzzle 1! Good luck!

For extra hints and the answers, visit newscientist.com/puzzleanswers2022



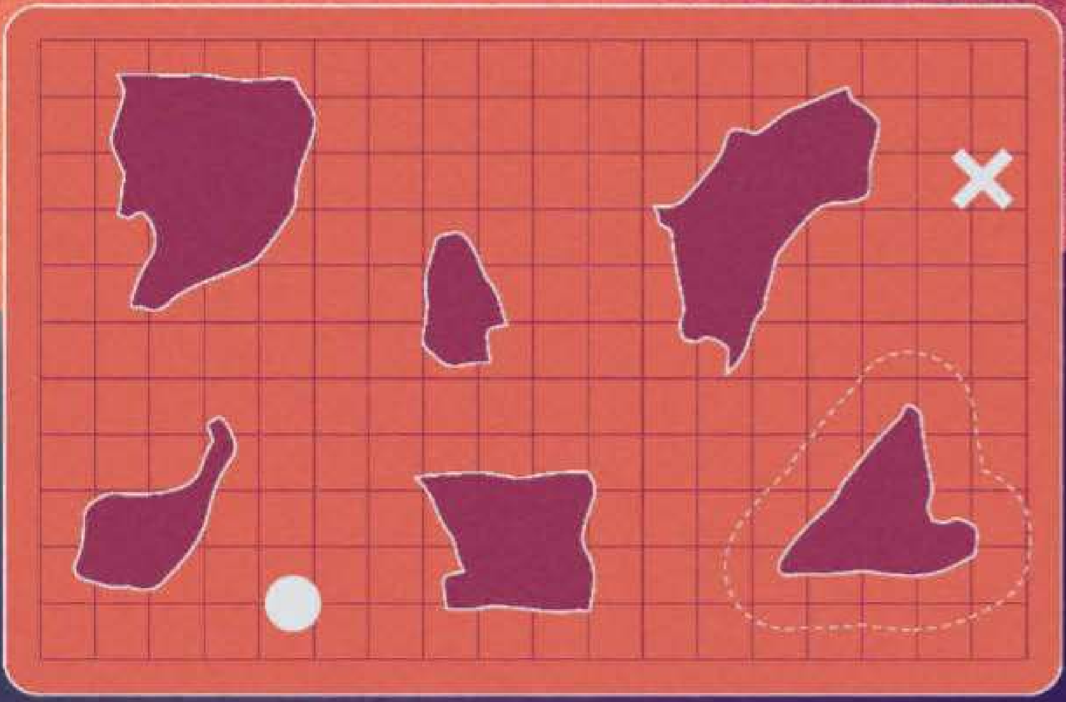
4 Elemental!

Identify these elements and construct an almost-crossword with them. (Thorium is in the correct place!)

HINT You will need to see how things fit together there…
This solution will send you back to a puzzle.

5 Perseverance

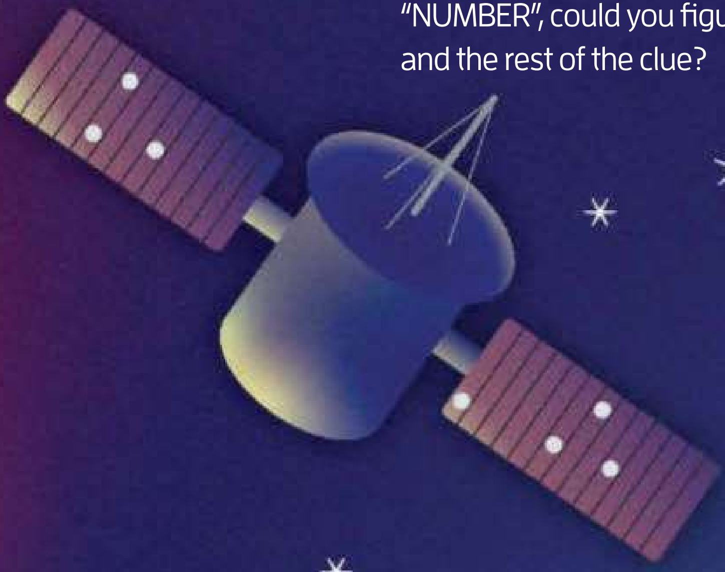
Plot a course from the dot to the "X". You can move around however you wish, but you may not leave the grid and you must stay at least 1 square's width away from all Martian stones! (One has been marked for you!)

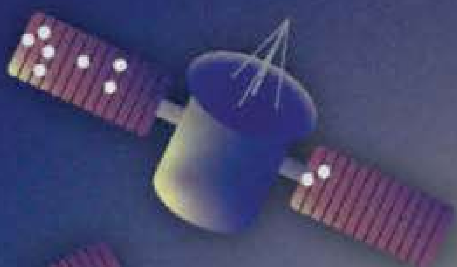


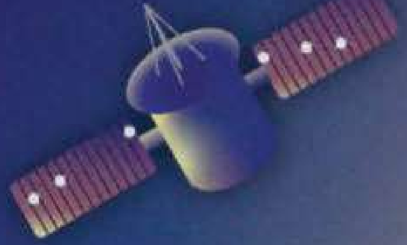
HINT Your path will look like a number, but not how we would write one nowadays.

2 Satellite signals

A three-word clue hides on the solar panels of these satellites. If I told you the third was "NUMBER", could you figure out why, and the rest of the clue?

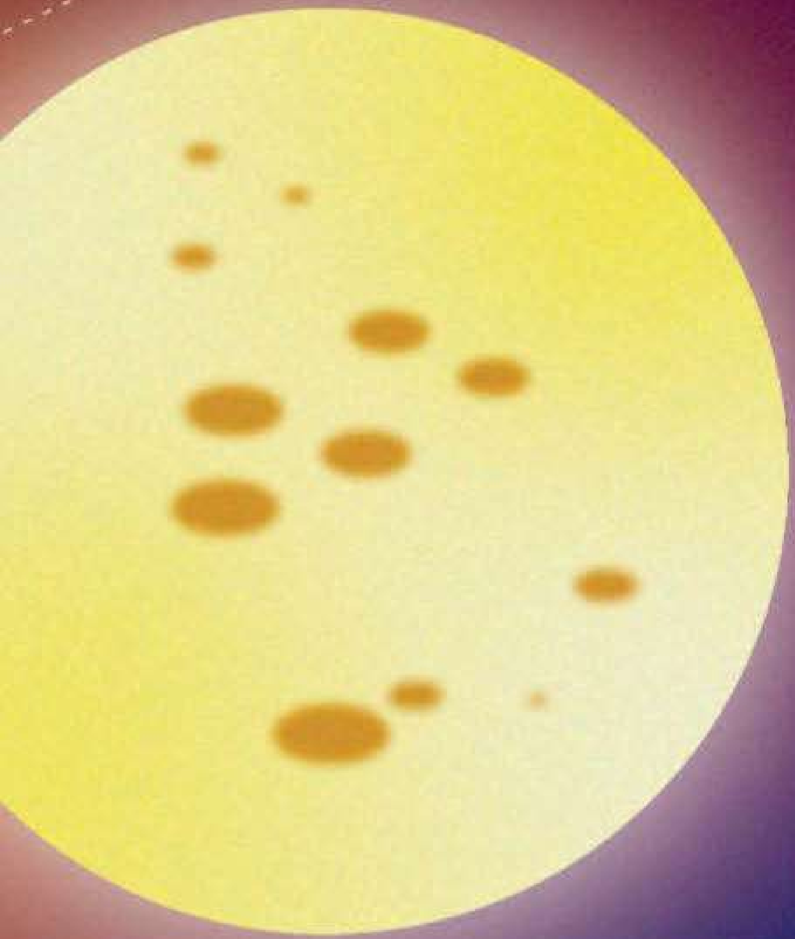


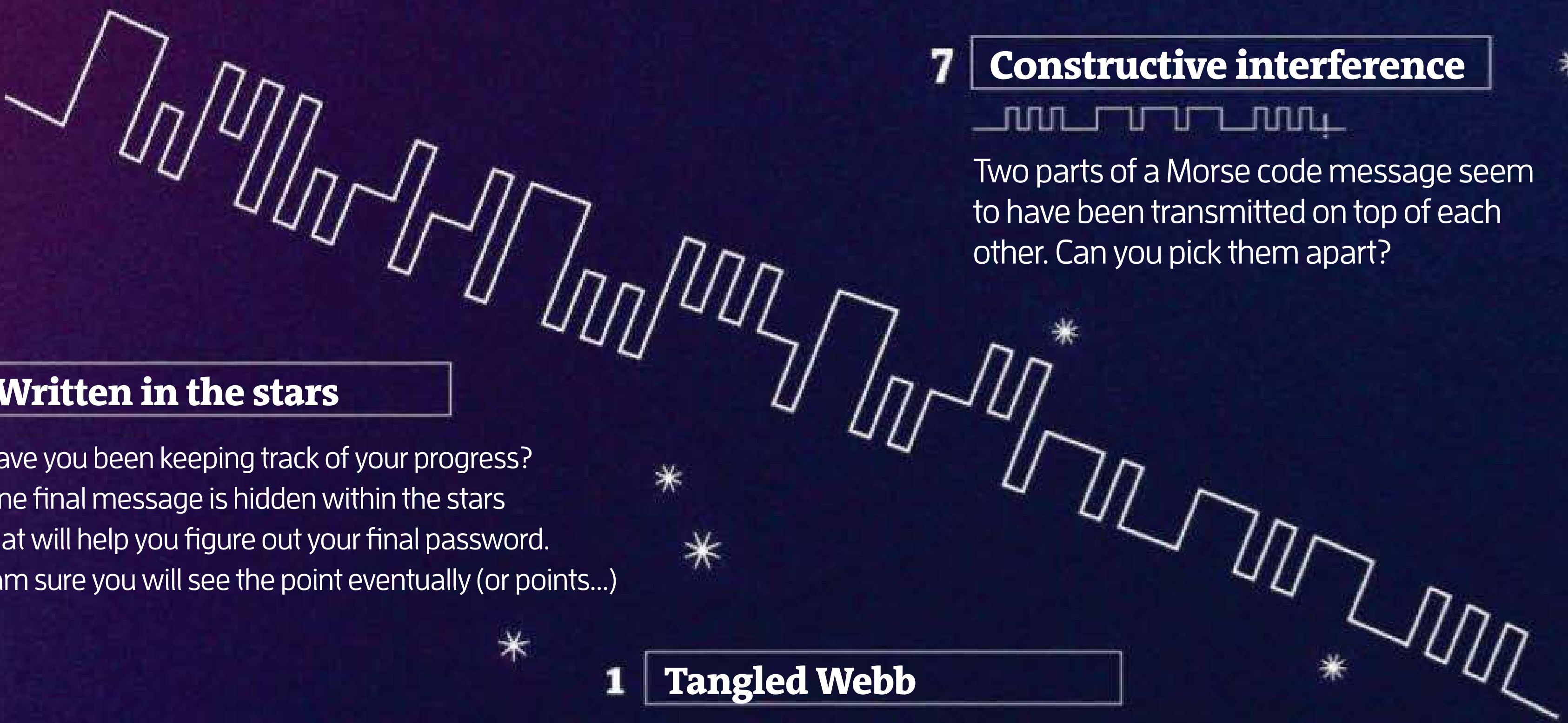




6 Sun spots

Connect up these spots from smallest to largest. This will direct you to what to solve next!





7 Constructive interference

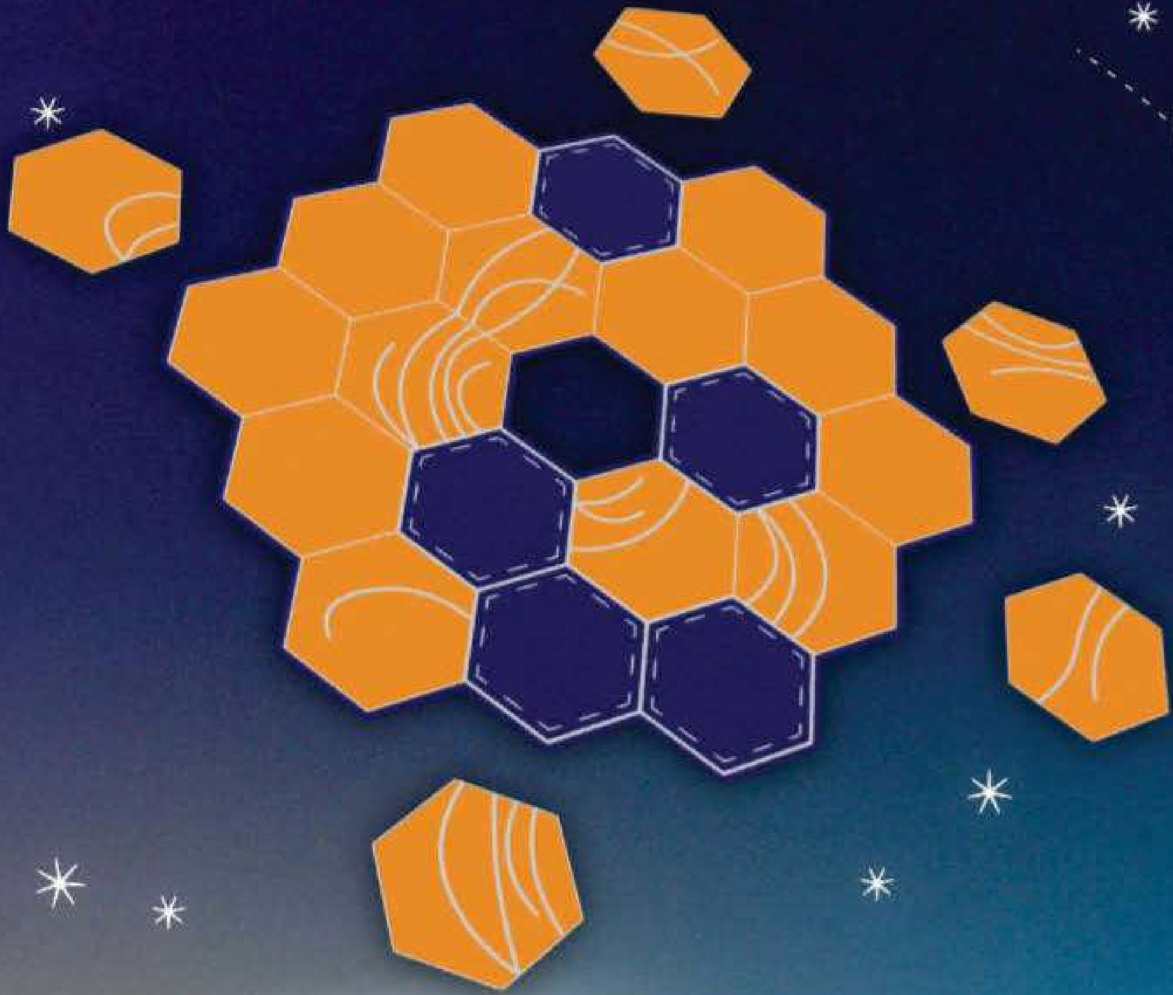
Two parts of a Morse code message seem to have been transmitted on top of each other. Can you pick them apart?

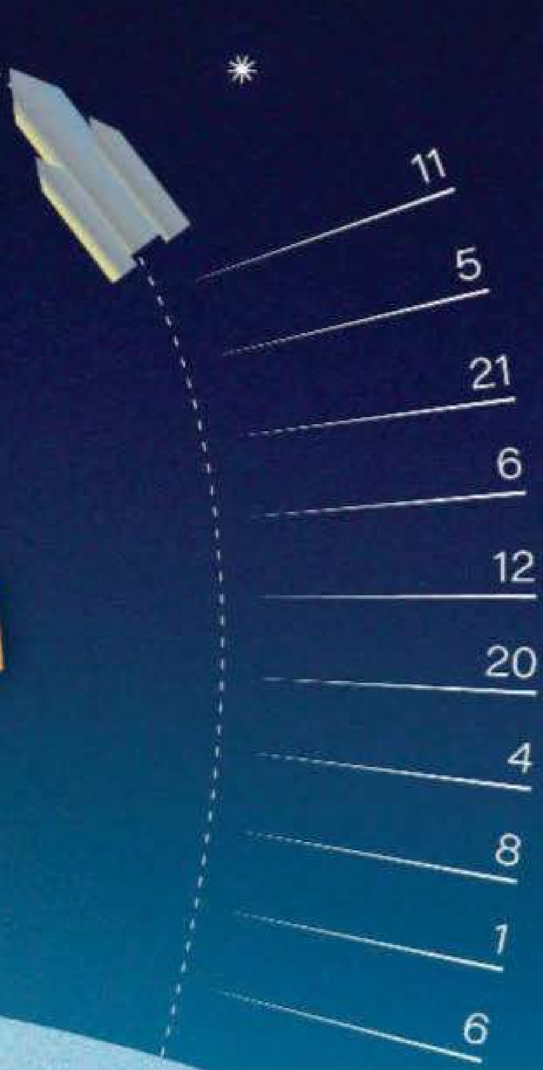
8 Written in the stars

Have you been keeping track of your progress? One final message is hidden within the stars that will help you figure out your final password. I am sure you will see the point eventually (or points…)

1 Tangled Webb

Place these loose hexagons back into the array. The markings on the hexagons will help you figure out where to put them. When assembled, you will find a number within them!



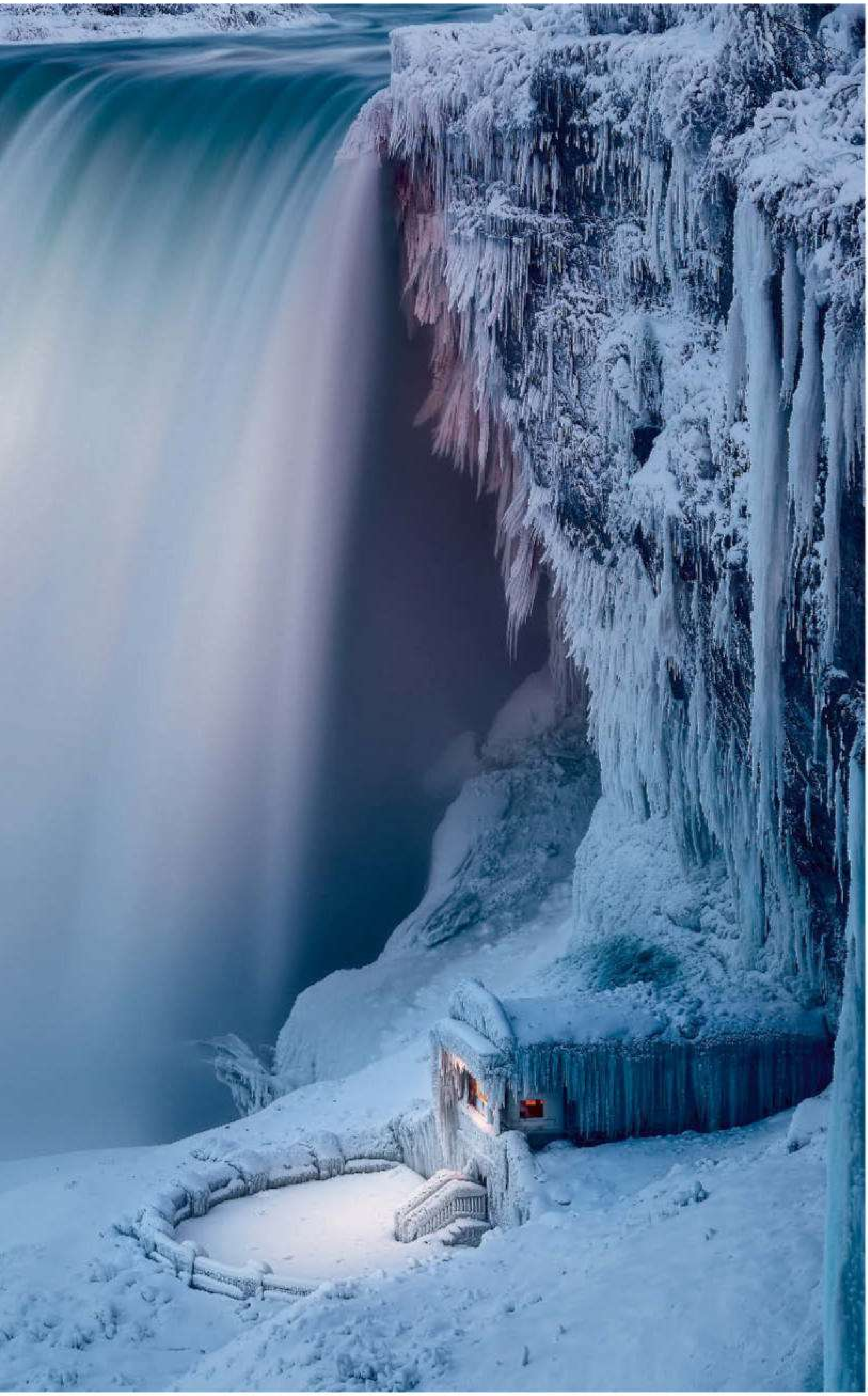


3 Blast off!

Ten numerical transmissions were received from this rocket. Five of them were fuel readings and five of them were altitude readings. The sum of the five fuel readings are 50 greater than the sum of the five altitude readings. Your solution is the lowest fuel reading minus the highest altitude reading.

CHRISTOPHER ISON

ZHENHUAN ZHOU



Winter wonder

Royal Meteorological Society Weather Photographer of the Year

A STORM captured in full fury and one of the world's most famous waterfalls coated in ice have won first and second prize respectively in the Royal Meteorological Society's annual Weather Photographer of the Year competition.

Christopher Ison's photo *Storm Eunice* (far left) captures the moment that the eponymous storm hit the port of Newhaven in the UK at high tide on 17 February. Eunice, one of the UK's worst storms since 1987, saw winds gust at up to 196 kilometres per hour. It met the criteria for a "weather bomb", also known as explosive cyclogenesis, caused when air pressure falls rapidly.

Ison said that when he learned the storm was responsible for the first ever red warning for the south coast, he knew he "had to find a spot to record it – this was going to be big!"

Zhenhuan Zhou's *Frozen* (near left) shows parts of Niagara Falls covered in ice, a phenomenon caused by mist and spray freezing over the top of the waterfall, though water continues to flow beneath the ice.

Niagara Falls' waters did stop once, in March 1848, when strong winds pushed ice from Lake Erie into the source of the Niagara river, blocking it completely.

Zhou's photograph captures the exquisite detail of the icicles on a building and the rock face. They are many metres long and look like stalactites.

All 22 of the shortlisted photographs can be seen on the Royal Meteorological Society's website: rmets.org/photography.

Liz Else

New Scientist Discovery Tours

FREE ONLINE EVENT

WONDERS OF THE ARCTIC: SCIENCE ON TOP OF THE WORLD

12 January 2023 8-9pm GMT, 3-4pm EST and on demand

The Arctic is a harsh yet beautiful region that has fascinated scientists and explorers for centuries. It's home to an array of unique wildlife above and below the waves, as well as over three million people.

Hear from biologist and *New Scientist* podcast editor Rowan Hooper and geologist and glaciologist Ulyana Horodyskyj Pena, who will lead this in-depth online discussion covering:

- The uniquely adapted wildlife of the region
- How humans could refreeze the ice in the Arctic circle
- The melting of Arctic ice
- All about the life of a scientist in such an extreme environment

Find out more and register your place at newscientist.com/arctic-event

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Features

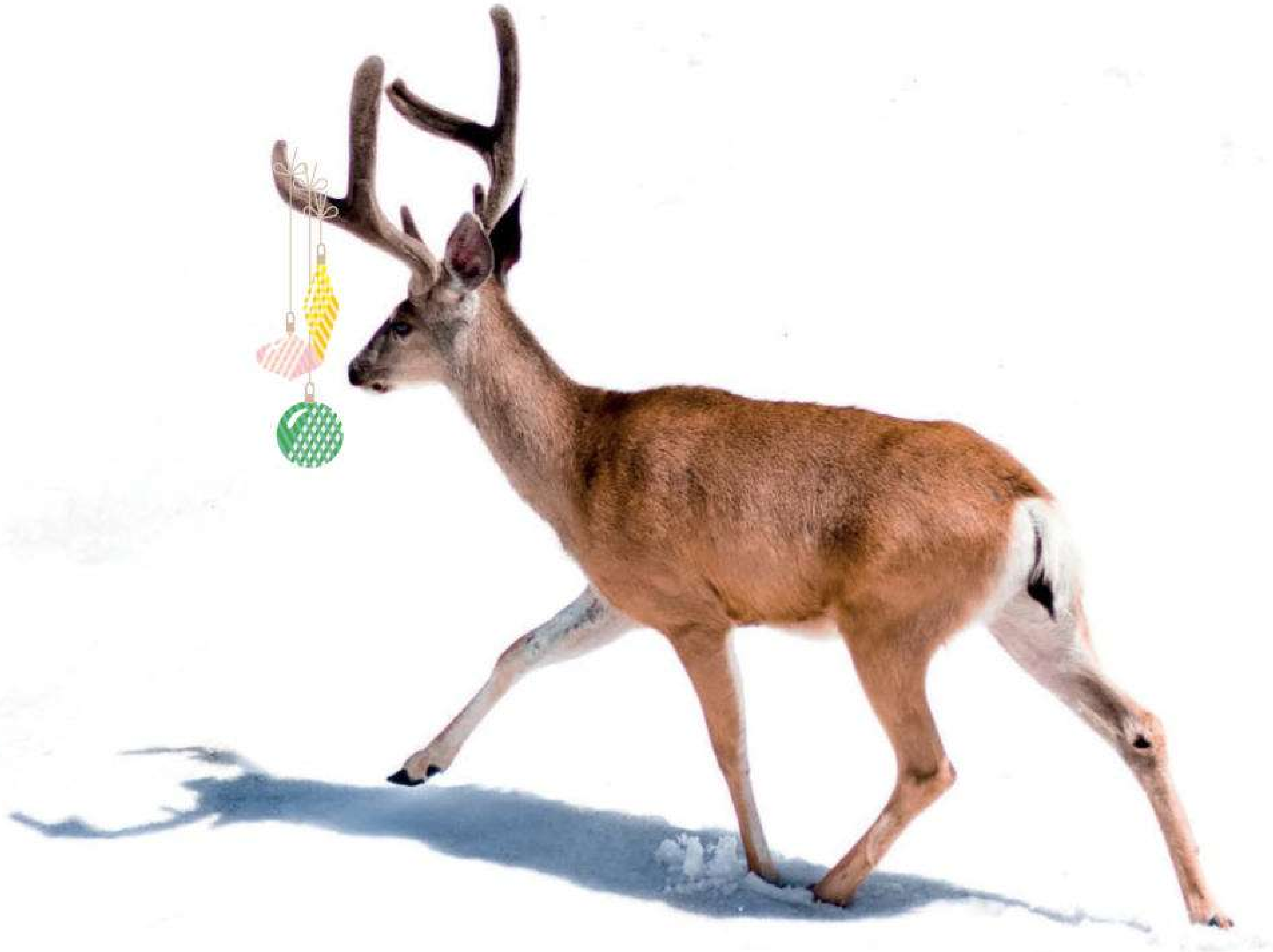
Quantum games
A sneaky way to beat your companions at board games p60

Talking to aliens
What would they think of us based on our broadcasts? p64

Cassette comeback
Why 90s tape technology is massive again p66

The origin of sprouts
The bizarre back story of a decidedly divisive vegetable p68

Meet Lazy Geoff
How extraordinarily idle animals get away with it p72



Festive fun and frolics

Over the next 29 pages, *New Scientist* presents a selection of the finest yuletide yarns for your enjoyment. Join us on the hunt for the mystical land where pharaohs got their gifts, uncover the colour-changing secrets of reindeer eyes, discover what makes high-end vegan food shine, learn why the surest route to a fun festive season may start with being kind to yourself and much, much more besides

UNSPLASH/JEREMY PERKINS

The hunt for Punt

A centuries-old search for the ancient and mysterious land of Punt may have been solved – by a baboon. **Colin Barras** investigates

WHERE do you find a gift for the pharaoh who has it all? The ancient Egyptians knew: suitably lavish goods were available in Punt. In this mysterious, far-flung land you could obtain all the gold, frankincense and myrrh a pharaoh might desire. To top it off, you could even throw in a baboon or two.

We have long known of the existence of Punt, a trading partner of the ancient Egyptians that provided them with expensive jewels, spices, ivory and animals. But hieroglyphic texts are frustratingly vague regarding the whereabouts of this extraordinary land, which means the hunt for Punt is one of the unsolved puzzles of Egyptology. Now, finally, we may be zeroing in on an exact location. Surprisingly, the clinching evidence isn't some newly discovered ancient map. Instead, it comes – quite literally – from the mouth of one of Punt's baboons.

The ancient Egyptians first began sailing to Punt about 4500 years ago, visiting the land infrequently for 1300 years. In Punt, the Egyptians could trade their grain, linen and other goods for aromatics, hardwoods and all manner of exotic products that were difficult or impossible to find in Egypt. "Some scholars describe the Egypt-Punt trade relationship as the origin of international peaceful commerce," says Nathaniel Dominy at Dartmouth College in New Hampshire. "So it's a big deal."

But there is another side to Punt. Consider *The Tale of the Shipwrecked Sailor*, an approximately 4000-year-old ancient Egyptian text that has been described as the world's earliest work of fiction. The story tells of a sailor marooned on a fantasy island. There, he meets a gigantic serpent that identifies itself as the Ruler of Punt. Ultimately the sailor is rescued, but not before the snake showers him with gifts (including baboons) and tells him: "You shall never more see this isle; it shall be changed into waves."

The story, and other poetic references to Punt, tell us the ancient Egyptians saw it as a mystical or otherworldy place. "Punt was also referred to as 'god's land', an imaginary landscape between this world and the realm of the divine," says Peter Dorman at the University of Chicago. There may be a few reasons for this. Punt was an important source of the fragrant incense that the Egyptians viewed as crucial for communicating with their gods in temple rituals, says Dorman. But the Egyptians rarely visited the land because it was so far away. "Those who knew about it did not necessarily have any direct information about it," says Kathryn Bard at Boston University in Massachusetts. Over time, "it seems it became almost a mythological entity", she says.

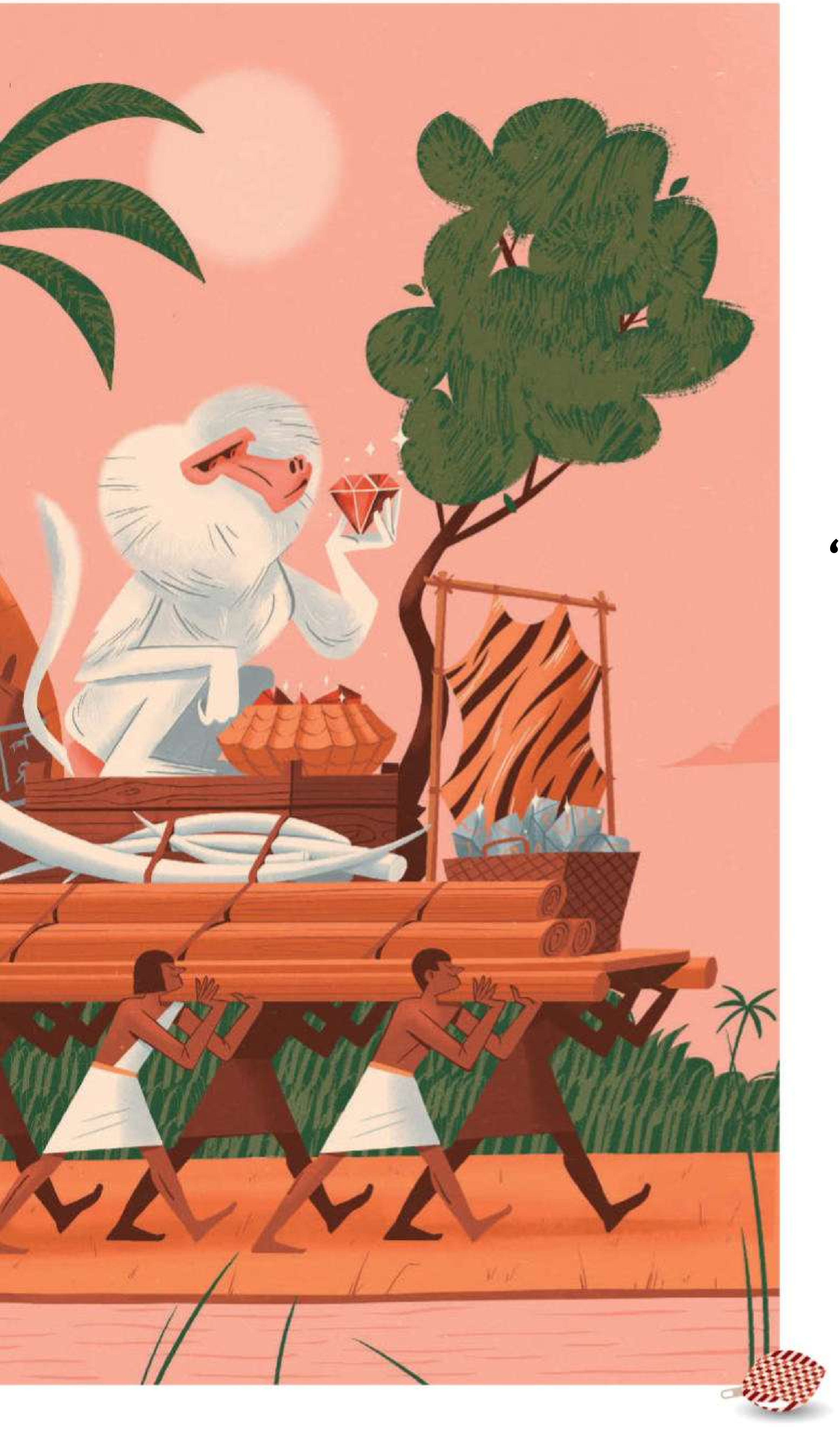
In the modern-day hunt for Punt, archaeologists have turned to the evidence left by the ancient Egyptians. The best documented expedition to Punt occurred around 1470 BC during the reign of female pharaoh Hatshepsut, with the Egyptians chronicling the trip in a series of pictorial reliefs carved onto the walls of a temple near what is now Luxor, Egypt.

They show the Egyptians sailing to Punt and bringing back goods that they then present to Hatshepsut. Punt is depicted as an exotic land of lush palms, dotted with distinctive mushroom-shaped buildings raised on stilts and accessed using ladders.

Eagle-eyed scholars noted that the Egyptian boats lacked keels, implying they would have been prone to rolling in rough waters. In the late 1990s, this led to the idea that the boats were unsuitable for seafaring. Instead, the argument went, the Egyptians must have reached Punt by sailing up the Nile, suggesting Punt was located in the resource-rich regions of what is now western Uganda, almost 4000 kilometres south of Egypt.

The idea has since fallen out of favour, and

ANTONIO SORTINO



for good reason. Between 2001 and 2011, Bard and her late colleague Rodolfo Fattovich conducted excavations at Mersa Gawasis on Egypt's Red Sea coast, a site already thought to have been an ancient port. In 2005, the pair found a stone slab that had been erected there to commemorate a voyage undertaken at the request of Pharaoh Amenemhat III in the 19th century BC. The text on the stone read: "His majesty caused me to go to lead the High Steward Senbef to Punt because I am pleasing to the heart of his majesty."

It basically tells us that this is the port from which they would send their ships to Punt, says Dominy. "It's mind-blowing. You can't get better evidence than this."

Or perhaps you can, because elsewhere at the site, Bard and Fattovich's team unearthed 43 wooden cargo boxes dating to the reign of Amenemhat III's successor, Amenemhat IV. "On two of them were inscriptions in hieroglyphs stating they contained wonderful things of Punt," says Bard. The boxes were empty, but she suspects they might once have contained incense.

"Punt was referred to as a landscape between this world and the realm of the divine"

Bard says the discoveries at Mersa Gawasis have been described as "putting a nail into the coffin of the idea that Punt was reached via a riverine route". But as astonishing as the finds are, they still don't give us an exact location for Punt – in theory, it could have been anywhere on either the African or Arabian coast of the Red Sea.

About 20 years ago, another clue emerged, in the form of an inscription on the wall of an ancient Egyptian tomb from the early 16th century BC. The inscription tells how the Egyptians had recently been attacked by the Kushites, who we know lived to the south of Egypt in what is now Sudan. Significantly, the Kushites had enlisted help from their neighbours. According to the inscription: "Vile Kush... stirred up the tribes of Wawat, the island-dwellers of Khenthennefer [and] Punt."

"To me, it's good evidence that Punt was on the African side of the Red Sea," says Bard. ›

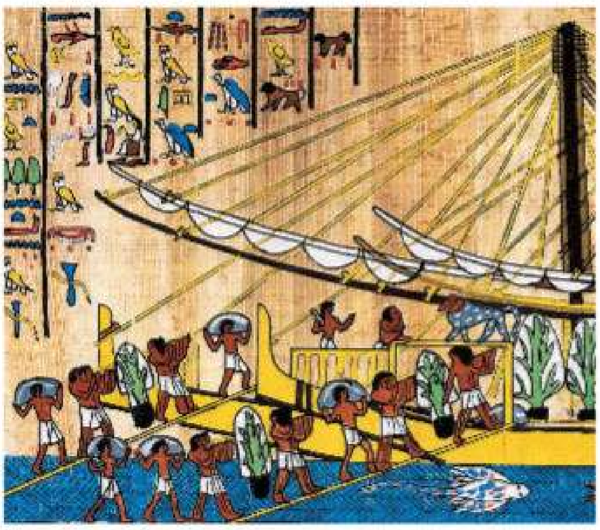
What's more, for the past few decades Italian archaeologists have been excavating at a site near Kassala, close to the modern border between Sudan and Eritrea. Bard says they have uncovered plenty of evidence of ancient Egyptian pottery fragments and other trade goods, making it a plausible location for Punt.

Because of this evidence, Fattovich wrote in a paper published posthumously in 2018 that the "problem of the location of Punt has been solved". Bard agrees with Fattovich's assessment. She suspects Punt's harbours probably lay along the coast of what is now Eritrea. "The hinterland of Punt probably lay in [what is now] the Kassala region of eastern Sudan," she says. "There are gold sources there and also incense trees."

The case isn't entirely closed, however. "We still have to debate the options," says Jacke Phillips at SOAS (School of Oriental and African Studies) University of London. "The Egyptian evidence [supporting Punt's location] varies and is sometimes contradictory over time." Perhaps that is because Punt was several distinct locations. Known expeditions to Punt were sometimes separated by centuries, so we can't be sure that the Egyptians always went back to exactly the same place, she says. Punt may have been the name the Egyptians gave to anywhere along the Red Sea coast where they could obtain exotic products.

Even if we are homing in on Punt, or one version of it, something is still missing. What has happened to the "wonderful things" the ancient Egyptians obtained there?

Enter the baboons. These animals meant a great deal to the ancient Egyptians. They were venerated as an embodiment of Thoth, an Egyptian god of wisdom. Baboons were also cared for, and mummified after their death. All of which is curious, given that the primates aren't native to Egypt. So where did the ancient Egyptians get their baboons?


DEAGOSTINI/GETTY IMAGES

A reconstruction of a relief showing the loading of goods onto a boat headed for Punt

To find out, Dominy and his colleagues analysed the remains of two hamadryas baboons (*Papio hamadryas*), both between 3200 and 3500 years old. They were found in Egypt in the 19th century and are now in the British Museum in London.

The researchers focused on isotopes of strontium in the teeth of one animal, and oxygen isotopes in the mummified fur of the second. Their analysis, published in 2020, showed that both baboons carried isotopic signatures unlike those expected of animals born and raised in Egypt, but similar to those of animals that come from portions of Somalia, and much of present-day Ethiopia, Djibouti – and Eritrea.

The obvious conclusion, says Dominy, is that the baboons came from Punt. As such, Dominy argues the two baboons are the first known Puntite objects found in Egypt. "There are other tantalising objects strongly associated with Punt," he says. "But to my knowledge nothing we can actually sample other than these baboons."

Bard doesn't agree that the baboons are the first known Puntite objects. She says the excavations at Mersa Gawasis uncovered obsidian and ebony fragments that the archaeologists traced to sources in Eritrea. Despite this minor disagreement, however, Bard does have a great regard for Dominy's work. "I think highly of his analyses," she says.

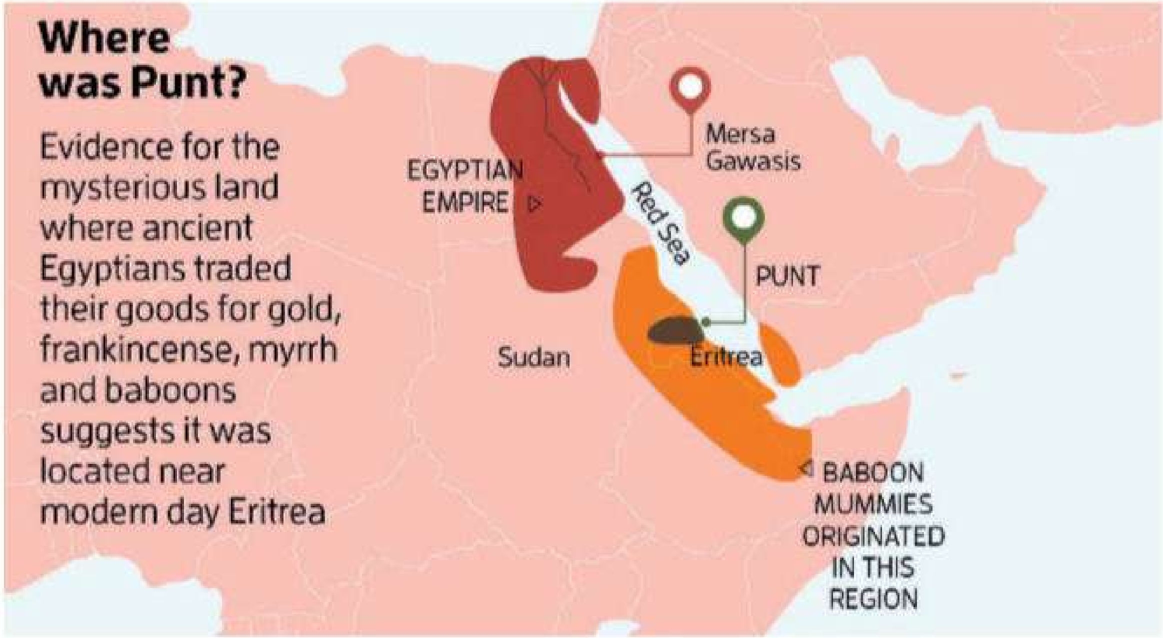
In separate work with different baboons, Gisela Kopp at the University of Konstanz, Germany, analysed ancient DNA from mummified baboons found in Egypt, some about 2700 years old. All the animals post-date the period during which the ancient Egyptians traded with Punt. Exactly why trade ended or what became of Punt isn't clear, but there are hints in the DNA that at least one of the mummified animals can trace its genetics to Eritrea – perhaps suggesting that the Egyptians were still sailing down the Red Sea to collect baboons even after Punt itself ceased to exist.

Which leaves just one mystery: why did the ancient Egyptians value baboons so highly, particularly when they are known for raiding crops and sometimes carrying disease?

Dominy is fascinated by a suggestion made in the late 1970s that, when the ancient Egyptians first came across hamadryas baboons, they noticed the animals have a habit of sunning themselves in the dawn light. According to the argument, the Egyptians interpreted this as evidence of the baboons welcoming the sun god Ra, indicating they were animals with divine connections.

"It's such a striking idea to me as a primatologist," says Dominy – although it hasn't been investigated formally yet.

Of course, we may never know for sure what the ancient Egyptians were thinking when they decided to worship Punt's baboons. On the flip side, Dominy points out we can only imagine what the Puntites made of the practice. The ancient Egyptians viewed Punt as an extraordinary land because of the products that could be obtained there. Perhaps the people of Punt viewed ancient Egypt as no less extraordinary because of the Egyptians' baffling habit of venerating pesky primates. ∎


Where was Punt?

Evidence for the mysterious land where ancient Egyptians traded their goods for gold, frankincense, myrrh and baboons suggests it was located near modern day Eritrea

Colin Barras welcomes any exotic presents from lands afar

Secret world beneath the snow

Each winter, animals take refuge in a fleeting sanctuary under the snow. **Ute Eberle** delves into its mysteries

CINDY GOEDDEL

A red fox dives into the snow, looking for rodents sheltering beneath the surface

ECOLOGIST Jonathan Pauli used to spend a lot of time keeping track of animals over winter – often across cold, harsh landscapes that seemed inhospitable to life. It always surprised him that as soon as the weather got warmer in early spring, insects would pop up. "Snow fleas would emerge from underneath the snow," Pauli recalls. Where, he wondered, had they been hiding?

Eventually, he discovered some old scientific papers from the 1940s and 1960s. They revealed a secret world that Pauli, a researcher at the University of Wisconsin-Madison, has been studying ever since: a hidden ecosystem under the snow. It is found in a clandestine space between the snowpack and the soil beneath, which is sheltered from the bitter cold and is where some insects, spiders, frogs and even small mammals spend at least part of the winter. Concealed from the world above, flies buzz, plants thrive and animals forage, hunt and give birth in this so-called subnivium (from the Latin *sub*, meaning under, and *nivis,* meaning snow). But what will happen to this winter wonderland and all the creatures it shelters as the climate warms up? That's the topic of Pauli's most recent research.

Every winter, as the white stuff covers up to 40 million square kilometres of the northern hemisphere, the subnivium forms wherever and whenever the conditions are right. "There needs to be around 20 centimetres of snow that is not too dense," says Ben Zuckerberg, also at the University of Wisconsin-Madison. Fluffy, light snow is best. As it settles on the ground, warmer air from the soil rises up, turning the snow at the bottom of the snowpack into water vapour. The resulting moisture condenses and refreezes on the cold layer above, creating a space above the soil that is usually a few centimetres high, with an icy ceiling.

In this shallow nook, temperatures hover around freezing, even if the air above the snow drops as low as -20°C (-4°F). There is no wind, either. "It's a refuge from ambient conditions that are much colder and more variable," says Pauli.

This relatively mild environment allows soil-dwelling insects like springtails and beetles to stay active during winter, along with some spiders and adult flies. Frogs hibernate in the leaf litter, which is kept at a chilly but stable temperature. There is light, too, filtering through the blanket above. Often, it is bright enough for mosses and evergreen shrubs to carry on photosynthesising. Some plants

›

are even known to flower under the snow.

Small mammals criss-cross the subnivium in domed tunnels, which allow them to roam and search for food. A few years ago, Eeva Soininen and her colleagues at the Arctic University of Norway set up camera traps in the subnivium and observed shrews, voles and other animals as they came and went.

Not only does the subnivium protect these small mammals against the worst of the cold, but it also hides them from many of the predators that prowl through the winter landscape. Although not every hungry beast is deterred. "Weasels actively hunt for mice and other rodents in the subnivium," says Pauli. "They find an access point, maybe under a tree, where they can squeeze into it, then run underneath the snow."

Bigger animals occasionally visit on particularly cold days or nights. "Grouses might fly up into the air, then dive-bomb into the snow," says Zuckerberg. Often, they snuggle into the warmer base layer of the snowpack for hours, as do mammals such as foxes and wolverines, to shelter from the wind.

L: MARKUS VARESVUO/NATUREPL; R: SUMIO HARADA/NATUREPL

Above: A willow grouse in Finland. Above right: A glacier lily bursts through the snow. Below: A bank vole emerges

Melting point

As winters warm up, what will happen to the subnivium? Studies in North America show that, since the late 1980s, snow cover has decreased by 0.8 million square kilometres per decade, and the snow season has grown shorter by about five days every 10 years since the early 1970s. Where snow still falls, there is often less of it, and more rain that packs it down into thinner, icier drifts. There are exceptions: parts of Scandinavia and eastern Europe have seen deeper snow in recent years.

Overall, however, the areas in which there can be a subnivium, and the time periods over which it can last, are shrinking. The subnivium itself is changing, too. Paradoxically, milder winters often make the subnivium colder, as Zuckerberg and Pauli reported in 2018. This is because there might be less snow to protect it and the snow that is there may become compacted by rain or sleet during mid-winter warm spells. Denser snow provides less effective insulation, says Pauli.

While some species will benefit from milder winters, researchers are already seeing that those animals and plants that rely on the warming effect of a thick snowy blanket will suffer. Yellow cedar trees, for example, grow all over the coastal, temperate rainforests of Alaska and British Columbia, Canada, and can live for more than 1000 years. But recently, their numbers have declined. Research has shown that these trees are dying off in areas where the snowpack has diminished. Without its insulation, the trees' shallow roots are left exposed to any spell of frost, and they wither.

Winter-hardy amphibians will also be hit. Wood frogs, for example, survive the cold by letting their bodies freeze. They have special substances in their blood that protect their cells from damage, while their bodies turn into something "a little bit like an ice cube", says Zuckerberg. In the stable microclimate of the subnivium, the frogs stay frozen until they thaw in the spring and resume their lives. But without this buffer, any warm spell will rev up the frogs' metabolism, only to have them freeze anew when the temperature drops. Research suggests this will cost them too much energy. Many of them are likely to die.

But a paper published in 2021 suggests there is good news, too. To test how quickly future climate change will affect the subnivium, Pauli, Zuckerberg and their colleagues erected 27 greenhouses across the Upper Great Lakes region in North America. The greenhouses – some located in forests, others in open fields – had retractable roofs that the researchers could open or close to warm the air by 3°C or 5°C above the temperature outside.

JANE BURTON/NATUREPL

They were amazed to find that 3°C of warming only shrank the spread of the subnivium by about 4 per cent and hardly diminished the duration for which it stuck around. "Contrary to our expectations, the subnivium was surprisingly resilient," the scientists wrote in their paper.

However, this changed drastically when the researchers simulated a temperature rise of 5°C. Should this become reality, "we predict that the subnivium's extent will decline by 45 per cent and its duration by over one month", says Pauli. "There appears to be a tipping point that we really don't want to cross."

Besides stopping climate change, there are additional ways to protect this ecosystem, such as planting understorey shrubbery, which helps build airy snow cover, or reducing areas for snowmobiling and skiing. The latter quite literally eases the pressure on the subnivium.

If you live in a snowy place, you might catch a glimpse of this buried ecosystem this spring. As the snow melts, look for the markings of the tunnels as they emerge from the forest floor or fields – the remains of a seasonal refuge against the cold. ▮

Ute Eberle dreams of a white Christmas under the subnivium

Conscientious cordon bleu

What does vegan haute cuisine look like, and can it fulfil our desire for some guilt-free luxury every now and then, asks **Jessica Bond**

Plant-based "seafood" platter from Holy Carrot in London

IT IS Saturday night and I am cooking for friends. I pour three glasses of red and carefully lay the fillet steaks in the pan. A crust begins to form as the carbohydrates caramelise. A few minutes on each side and they are ready. I bite through the crunchy exterior into a juicy centre that fills my mouth with a delicious hint of umami. I smile at my friends. I have managed to cook the steaks perfectly – and I have a clear conscience. No cow died for our enjoyment and the greenhouse gas emissions were minimal. Our fillet steaks were entirely made from plants.

Vegan food is having a moment. McDonald's, Subway and Burger King have all launched vegan products in recent years, Impossible's "chicken" nuggets and "sausage" patties are sold in UK pubs, and the plant-based section of my supermarket has become an aisle. But something is missing. The processed food and fast food markets are well catered for, but what about those of us who would prefer to tuck into a filet mignon than a Filet-O-Fish?

I'm talking about fine dining. For me it is a real treat, a licence to eat beautiful ingredients or experience extraordinary meals that I could never cook myself. Increasingly, though, this indulgent pursuit is starting to feel, well, overindulgent.

Historically, fine dining involves a lot of planet-destroying meat and dairy, and livestock are collectively responsible for about 15 per cent of greenhouse gas emissions.

The good news is that vegan foods are spreading to the fine-dining world. But what does vegan haute cuisine look like, and can it compete with traditional cordon bleu?

To answer those questions, we first need to consider what makes luxury food so luxurious. Let's start with the simplest explanation: the ingredients themselves. To many Western palates, fine dining has long been associated with high-quality meat, fish and dairy.

One way to emulate this is by creating plant-based foods inspired by these traditional luxuries. Visit Délice & Sarrasin in New York, for instance, and you can try its crabless crab cakes made from dehydrated lemon peel, yellow pepper and seaweed, or go to Gauthier Soho in London to sample "faux gras" made from walnuts, lentils and cognac.

Meat mimics

To get even closer to the real deal, food companies are working on recreating luxury foods themselves. My plant-based filet mignon was made by Juicy Marbles, a US start-up that attempts to recreate the texture and prized fat marbling of high-end cuts of meat with layers of soya and wheat protein fibres, mimicking the musculature of meat. My friends and I felt it was more akin to salt beef than fillet steak.

Plant-based "meat" does have the seal of approval from Alexis Gauthier, chef patron of Gauthier Soho, which was awarded a Michelin star in 2011. He uses a product from Redefine Meat in one of his dishes, and is impressed. "They've managed to recreate this fattiness that is perfectly integrated within the fibre," he says.

Other companies are hot on their heels, creating plant-based versions of caviar (made of kelp), tuna (created from seawater, algae and rice infused with a fermented culture) and serrano ham (made using wheat gluten, rice flour, coconut oil and beetroot).

But when it comes to precisely replicating high-end meats, one technique goes above and beyond: cell-cultured meat. This is food made using stem cells taken from an animal and coaxed into becoming the muscle, fat and connective tissue that comprise regular meat. The cells are grown around edible scaffolds to recreate the various cuts of meat we are used to. They may not be › vegan, but they get close to being cruelty free.

The first meal made from lab-cultured chicken cells was sold at 1880, a members' club in Singapore in 2020, and there are now several start-ups around the world racing to produce all sorts of foodstuffs in a similar way, including caviar and foie gras.

But while the ingredients themselves are a big draw, they aren't the only element that creates a high-end dining experience. "Luxury has to be something that lots of people desire and, at the same time, most people don't have access to," says Marijke Van der Veen at the University of Leicester, UK, who has studied food's role in human culture.

Inaccessibility can be a product of rarity – a tin of diamond caviar from a sturgeon carrying a rare gene for albinism, for example, or a bluefin tuna of a subspecies classed as vulnerable because of low stocks. It can also be a result of resource-intensive production methods. Japanese Wagyu beef is widely seen as the pinnacle of such meat thanks to its superior juiciness and tenderness from the marbled fat running through it. This intramuscular fat distribution is related to heat stress and diet, says John Cadieux, global beef ambassador for the US Meat Export Federation, which is why the cows are protected from the heat and fed sumptuous food. Japan's Olive Wagyu cows, for example, are fed on inawara rice straw, Italian ryegrass and pressed olive pulp. Just a few are slaughtered each month.

Muskmelon massage

The vegan answer might be to create rarity by controlling what and how much gets made of any single item. For instance, Gauthier says that exclusivity could be maintained by making a line of cultured cells from "the best Kobe Wagyu cow", and then restricting its use to maintain scarcity and exclusivity.

There are also many non-meat foods that are incredibly rare and are highly prized in some cultures, which would lend themselves well to a more sustainable fine-dining establishment. In Japan, for instance, certain kinds of melon would give Wagyu cows a run for their money in terms of labour-intensive production. Crown muskmelons are hand-reared for 100 days with extreme care, reportedly massaged and fitted with caps to prevent sunburn.

But exclusivity isn't solely about ingredients or how expensive they might be. It is also about who is stirring the pot and the story they tell. Chefs like Heston Blumenthal or Ferran Adrià won their restaurants' Michelin stars

JUICY MARBLES

Clockwise: Juicy Marbles's plant-based "filet mignon"; Holy Carrot's maki selection; Chef de Partie at Gauthier Soho, London

ANTONIO OLMOS/ALAMY

FROM MICHELIN-STARRED MEAT TO LUXURY VEGAN FARE

Alexis Gauthier's Damascene moment came after reading *Antispéciste* by Aymeric Caron, a book about putting animals on an equal level with humans. He now refers to all animals like he would a person. "I closed the book and decided that I will never ever eat someone who has lived and then died," says Gauthier.

He initially struggled to square his veganism with his career as a classically trained French chef, but, one by one, he removed animal products from his menu. When he reopened after the covid-19 lockdowns, Gauthier's London restaurant was 100 per cent vegan.

"It was an amazing challenge," he says. Discoveries included finding that a sauce's flavour doesn't have to be derived from the animal, but can come from what it had been feeding on. This meant a reduced lamb jus could be recreated with mosses and mushrooms the lamb would eat, reduced alongside the fat from plant-based meat alternatives.

He serves a dish called Tomorrow, a cube of meatless lamb shank, made of wheat, soya and potato protein, treated with the reverence and presented with all the accoutrements its real-meat counterpart would command.

New approaches also include aubergine as the starting point for patisserie and developing a way of treating a watermelon so it has the texture of meat. "It's just like the muscle of an animal," says Gauthier. "This is what we were meant to eat. Something we can pick, something we can take from a branch. Not something we've killed."

HOLY CARROT

> **"Today, luxury food is about what you can only eat in one single place"**

through their innovative approaches to fine dining. Vegan restaurateurs wanting to emulate this kind of success know their pulling power must arise not only from the ingredients they use, but also the uniqueness of the experience they offer. "I feel like I'm a scientist not a chef," says head chef Elena Savchuk of Holy Carrot, a vegan restaurant in Knightsbridge, London.

The playfulness and storytelling that often combine to create the perfect high-end meal can easily be emulated in vegan restaurants. For instance, one of the tasting menus served at ONA, France's first Michelin-starred vegan restaurant, is inspired by Homer's *Odyssey*, thanks to head chef Claire Vallée's first calling as an archaeologist.

And, of course, any ingredient can be elevated to luxury status in the right hands. Think of a turnip grown in the specific terroir of the chef's kitchen garden, harvested at the perfect point in the season, on the day it was served, before being transformed into 10 wildly different morsels that delight the tongue and surprise the eyes. "The rarity is the creativeness," says Gauthier. "It's in the brain of the chef being inspired by the look of the ingredient, by its smell, by where you stand on the planet at which time of the year. It's luxurious because you can't duplicate it."

The new luxury is a meal you can't enjoy anywhere else on Earth, says an industry insider familiar with Michelin guidelines, who wished to remain anonymous. "Today, it's not about an expensive product, luxury food is about what you can only eat in one single place," they say.

Social context is also vital for any fine-dining experience. As uncomfortable as it might be to admit, luxury foods still flag social status. High-end restaurants come with unwritten rules about which cutlery to use, the order of dishes, the silver service and glassware, and the cachet of getting a table in the first place. "Going to those kinds of places and having a reservation a year in advance, that's a social signifier of status," says Esther Papies, a cognitive psychologist at the University of Glasgow, UK, whose research has demonstrated that context is central to people's associations with food.

For those at the vanguard of the vegan fine-dining movement, it is essential that this entire experience is maintained. When Gauthier made his restaurant menu at Gauthier Soho entirely vegan after the covid-19 lockdowns, he knew he couldn't steer too far from what his customers had previously enjoyed (see "From Michelin-starred meat to luxury vegan fare", left). A key part of this was preserving the trappings of the traditional experience: the crystal, the sommelier and the maître d' lovingly describing the ingredients – and not forgetting the elevated price. "We want customers to leave still thinking that they'd had the most luxurious gastronomic French experience they had hoped for," says Gauthier.

This focus on maintaining the perception of luxury is smart for recruiting more people to plant-based diets, says Papies. Research has shown that, beyond the taste experience, the occasion and the people you share it with are at the forefront of people's minds when they think of food.

As for me, I am excited by a whole new world of plant-based luxury meals that I have never experienced before. I have yet to taste Blumenthal's "Meat Fruit" (a "mandarin" made of real foie gras enveloped in orange jelly peel). It is heartening to know that I no longer need to – it is possible to enjoy this level of culinary creativity without the moral or environmental hangover the next day. ∎

Jessica Bond is available to test out guilt-free fine dining experiences any day of the week

Polar vision

Reindeer can see so well in the darkness of the Arctic winter thanks to a special superpower, discovers **David Robson**

AS SURPRISE presents go, two pots of reindeer eyeballs are hardly at the top of most people's wish lists – even if you are a vision scientist like Glen Jeffery.

It was 2008 when the macabre packages arrived. They had been sent by two of Jeffery's colleagues in Norway, who wanted him to investigate how reindeer manage to see in the winter, when the sun fails to rise above the horizon for months on end. "Half the eyeballs were collected in midsummer and half the eyeballs were collected in midwinter," says Jeffery, who is based at University College London. To begin with, he wasn't optimistic. A quick dissection, he suspected, wouldn't reveal anything of particular interest.

But, to his surprise, when he took an eyeball from each pot and cut them open, a striking difference was visible straight away. Whereas the inside back surface of the summer eyeball was golden with a turquoise halo, the winter one was an astonishingly deep blue. It suggested that the eyes of reindeer – known as caribou in North America – could change with the seasons.

Jeffery's curiosity was piqued. And so began his mission to understand the mysterious colour-changing structure in the eyes of reindeer, and the impact it has on their ability to see in the dramatically different seasonal light conditions of the Arctic.

Like all good scientists, Jeffery is keen to pay his debt to his forebears. He admits he is standing on the shoulders of the British photographer and ophthalmologist George Lindsay Johnson. Working in the late 19th and early 20th centuries, Johnson spent days in a darkened room at London Zoo studying the eyes of its residents, including rodents, bats and cheetahs. The result was a series of 50 extraordinary illustrations, including depictions of a biological mirror found at the back of the eyeball called the tapetum lucidum.

Tapeta are common in nature, found in the eyes of many mammals, reptiles, fish and invertebrates, such as spiders, but not in birds or certain primates, including humans. They are the reason why the eyes of cats glow

STEFANO UNTERTHINER

when illuminated by car headlights.

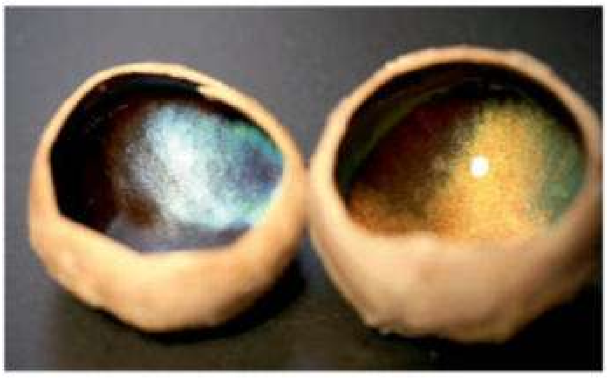
The positioning of this shiny surface reminded Johnson of a photographic technique that involved placing a mirror behind the film, reflecting any light not captured in the first pass through the material so it would have a second chance to trigger the necessary chemical reaction. Something similar, he suggested, was occurring in the animals he studied, many of which were active at night and in the low light of dawn and dusk. The tapeta allowed them to make the most of the little light available, by reflecting it back through the translucent retina.

Surprisingly, however, few biologists subsequently took an interest in the structure or function of this strange reflective surface. "It was a fundamental building block in visual systems that we tended to ignore," says Jeffery. Those who have bothered to look at the tapetum generally accept Johnson's idea that its reflectance improved the sensitivity of vision. But until Jeffery opened those pots of eyeballs, no one had investigated whether the tapetum could be tuned to the changing seasons. Could it be that the morphing of this structure gave reindeer vision a further boost beyond that of a regular tapetum?

Following that initial discovery, Jeffery arranged multiple visits to Norway, where he could examine live animals. The changing colour was apparent, he says, as soon as you looked into their pupils. To determine the range of their vision, Jeffery's team inserted a gold electrode under the eyelids of animals that had been anaesthetised, to detect the electrical signals generated by different wavelengths of light. The measurements, published in 2011, showed surprisingly high sensitivity in the UV range. Experiments have since revealed that the corneas and lenses of reindeer's eyes are transparent to a relatively high percentage of UV light, whereas those of humans, for example, absorb most of it.

Fleeting blue twilight

With these anatomical discoveries, and known seasonal changes in natural light, the deep blue of the reindeer's tapetum in winter started to make sense. In the polar winter, the sun is permanently out of sight. But for a few hours a day, it rises close enough to the horizon for shorter wavelengths of light to be scattered by the atmosphere onto Earth's surface, creating a kind of twilight. "It is a totally blue-saturated environment," says Jeffery – and it also contains a relatively large amount of UV light.


GLEN JEFFERY

Dissected reindeer eyes, from winter (left) and summer (right)

The evolved changes to the lens and cornea of reindeer eyes allow the retina to receive this light – but even then, the low levels of illumination would make vision difficult. The deep blue colour of the tapetum, however, enhances its reflectance at those shorter wavelengths, so more light is scattered back through the retina.

Since the blue tapetum scatters the light in multiple directions, the result is a somewhat blurred image. But the enhanced sensitivity would nevertheless aid the detection of food sources such as lichen, which absorb UV light. To the reindeer, this would appear as a darker patch against the brighter surrounding snow. Since animal hair absorbs UV light, greater sensitivity at this wavelength should also help reindeer spot predators, such as wolves or polar bears.

SPECTRAL SIGHTS

Imagine you are standing in the still of the polar night – only to see bright flashes of light dancing across the horizon. You may feel a little spooked. This is the reality for reindeer today as human infrastructure encroaches on their habitats. It may not be visible to most human eyes, but electric power lines release sparks of UV light. "All of a sudden, out of the corner of their eye, they'll see something jumping about which isn't a reindeer," says Nicholas Tyler at the Arctic University of Norway in Tromsø. "And if you are a reindeer, you don't waste time – you go in the opposite direction."

Tyler's research suggests that reindeer will try to stay several kilometres away from power lines, which vastly reduces the amount of ground they are able to graze on. Unfortunately, there is no technological solution to the problem, which threatens the livelihood of Sami herders in northern Europe, who are struggling to find enough land to graze their reindeer. As a result, some groups of herders have started to sue the power companies and have received compensation, says Tyler, who has acted as an expert witness for the herders.

In his latest study, published earlier this year, Jeffery worked with the astronomer Robert Fosbury, an emeritus professor at the European Southern Observatory in Garching, Germany, to explain how the colour change occurs based on the structure of the tapetum's surface. Images from electron microscopes had previously revealed that the tapetum is made of parallel fibres of the protein collagen, which are arranged in layers with water filling the gaps in between. The pair predicted that removing the fluid would pull the fibres closer together and change the wavelengths that the surface reflected. When they placed some tapeta on filter paper and recorded the changing reflectance as the water evaporated, within a couple of hours, the gold colour had morphed into a deep blue.

But how could this transition follow the calendar so predictably? Jeffery suggests that, in the winter darkness, the pupil is permanently dilated, leading to a build-up of pressure within the eyeball. This would squeeze out the fluid by pressing against the tapetum.

Other biologists have found themselves blinking with surprise at Jeffery's discovery. "It's super interesting," says Nathaniel Dominy at Dartmouth College in New Hampshire. "We'd never thought that the tapetum could be adjusted." He would like to see whether a colour-changing tapetum is found in other animals – such as musk oxen – that live in the same kinds of environments as reindeer. Such studies may help us to better understand this trait's evolutionary origins.

Jeffery thinks similarly, and is concerned about how UV light in human environments may be interfering with reindeer vision and preventing them from grazing in their normal habitats (see "Spectral sights", left).

Those tubs of eyeballs may have started out as a rather unwelcome present – but they have sparked Jeffery's passion for reindeer and their deep blue tapeta. Let's hope that this year he gets something slightly less gruesome under his Christmas tree. ∎

David Robson has no eye deer what to get his nearest and dearest this Christmas

Quantum board games

Is there a way to guarantee that you beat your family at games? There sure is – if you tap into the quantum world, says **Philip Ball**

THERE was a time when I could be certain of beating my kids at games. Whether it was chess, cards or my personal favourite, Exploding Kittens, I could sit down confident in my superior abilities. Sadly, those days are gone. My children are teenagers now, and the occasions when I manage to outwit them are dismayingly rare. But this holiday season, I have cooked up a plan to get my own back.

My kids have the advantage of nimble-minded youth. But I am the only one in the family familiar with quantum physics: a famously strange world where, as this year's Nobel prizewinners in physics showed, objects can seem to be in instant communication over any distance via a phenomenon called entanglement. I have now discovered a handful of games where my knowledge of quantum theory is going to give me the upper hand. They may be a little more exotic than snakes and ladders. They may even require a quantum computer to play properly. But did I mention that I really, really want to beat my kids?

SPENCER WILSON

My first discovery is a puzzle set by mathematician Leonhard Euler in 1779. He imagined a group of 36 army officers, each assigned to one of six ranks and six differently coloured regiments. Could these officers be arranged in a 6×6 grid so that no regiment or rank is repeated in any row or column?

I will watch my family struggle, before smugly announcing that it is impossible. In the 1960s, mathematicians showed that, while there are solutions for similar games involving 3 × 3, 4 × 4 and 5 × 5 grids, there is – strangely – none for 6 × 6. But then I will say that I can do it anyway thanks to my quantum know-how.

The credit goes to Suhail Rather at the Indian Institute of Technology Madras and his colleagues, who showed earlier this year that Euler's puzzle can be solved – providing the officers are made quantum mechanical. Such soldiers can be placed in "quantum superpositions" of their possible states, which means an officer can be, say, partially a red colonel and partially a blue lieutenant. That is, unless we actually look at one, whereupon this act of observation "collapses" the officer's quantum state to one thing or the other.

Now the officers in each row and column aren't so much different in terms of rank and regiment, as mutually exclusive in terms of their superposition states of rank and regiment. The officers also need to be entangled – meaning that collapsing the state of one officer by measurement affects how another collapses into a complementary state in just the right way to satisfy the rules.

To demonstrate this game for real, we would need a quantum computer to encode the information about the soldiers. I don't have one handy at home, but we could log into a cloud-based quantum computer, such as those offered by IBM or Google. I suspect my family will think all this is cheating. But, hey, the whole world is fundamentally quantum in the end, so what's the problem?

After trouncing the family at Euler's square, how about a simpler game like noughts and crosses (also known as tic-tac-toe)? This involves two players alternately drawing Xs or Os on a 3 × 3 grid. To win, one player must place three of the same mark in a horizontal, vertical or diagonal row.

The traditional version generally ends in a stalemate, but with quantum rules there is much more room for cunning strategy. On each go, players of quantum noughts and crosses make entries on a pair of spaces that are then in superposition on the grid. If you like, the player's entry is "delocalised". This means we don't know which of the two grid spaces it will end up in until a player elects to "measure" one of those grid spaces, determining whether the entry is there or not.

You can even make an entry into a space that the other player has already used, knowing that, on measurement, only one entry or the other will be permitted. Again, we would have to set this all up on a quantum computer.

In effect, each entry sets up a new parallel entangled game, while measurements gradually collapse the grid to just one of them. Part of the strategy lies in choosing when to measure and collapse a grid space, whereupon its entry is fixed and no further entries are allowed there. My familiarity with quantum mechanics should give me a head start on my family. Though, if mastering other new technologies is any guide, I might only have about half an hour before the kids overtake me.

Quantum telepathy

For the last game, I am stepping things up a notch. My kids aren't going to know what's hit them, because this time I am making use of my secret weapon: quantum pseudotelepathy.

The Mermin-Peres magic square was devised independently in 1990 by quantum physicists Asher Peres and David Mermin, and, like noughts and crosses, it uses a 3 × 3 grid that two players fill out in successive moves. However, for this game, the players assign values of +1 or -1 to each grid space, instead of Xs and Os, and rather than competing, they are trying to collaborate to win together without conferring.

A referee assigns one player a random row and the other a random column to fill out. The rule is that the product of every column (found by multiplying together the three numbers in it) has to equal +1 and the product of every row must equal -1. The players win a round if they both assign the same value to the square where their column and row overlap.

There are nine possible row and column combinations, but it isn't possible for the players to win all nine of these rounds – there will always be a space where what each player needs conflicts. Once again, I will let my family struggle with this fiendish game before showing them how it can be played to perfection with a quantum twist.

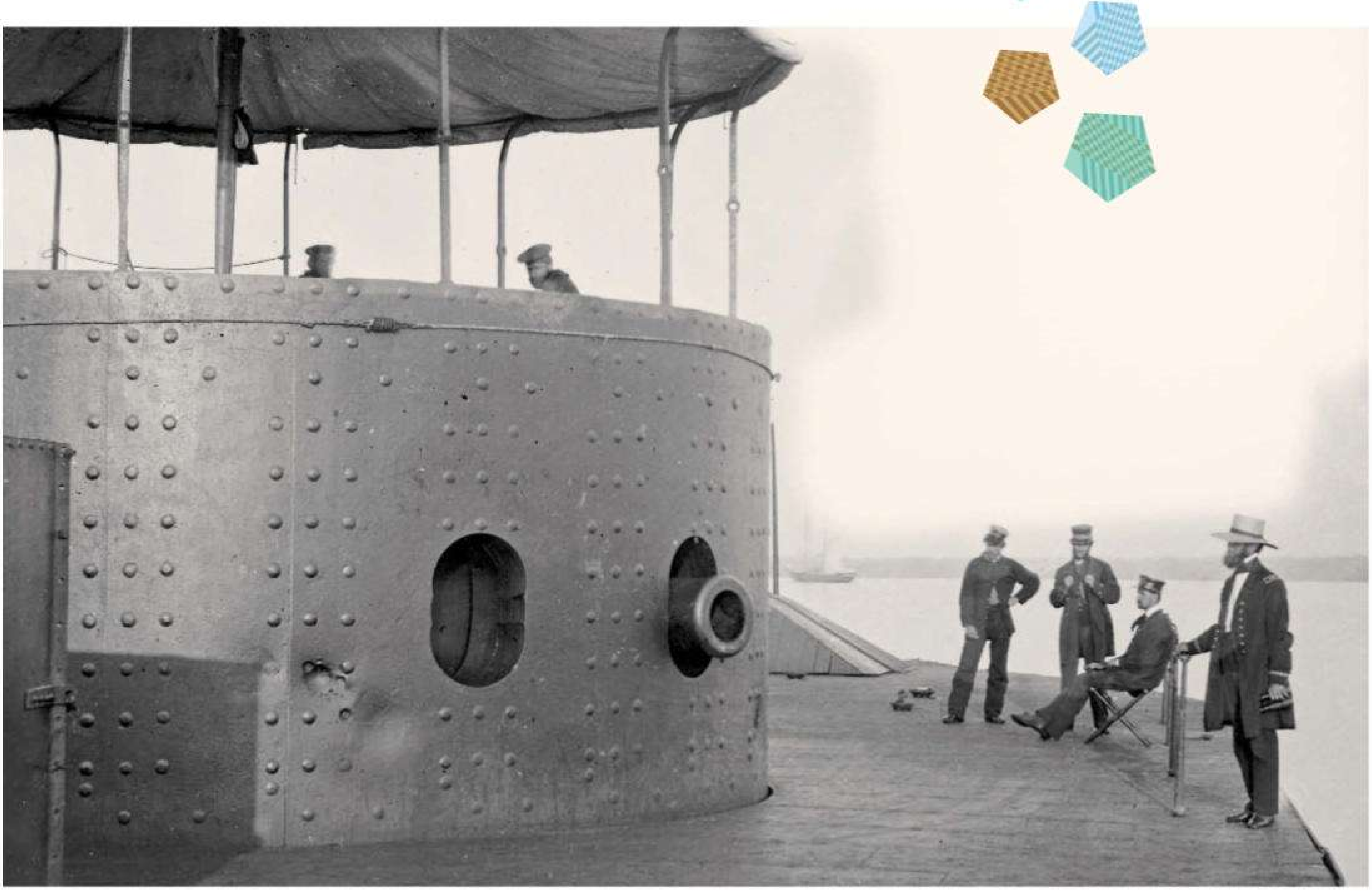
The key is to fill in each square with quantum bits (qubits), which can take the value +1, -1 or a superposition of both. Players now fill each space with a pair of qubits, and the product of the pair gives the value of that entry: for example, if they measure to be -1 and 1, the value is -1 × 1 = -1. When resolving what these values are, we only measure one row and one column at a time. This means that different classical outcomes can be obtained from identical quantum entries, depending on whether we measure the entry as part of a row or column. For instance, the top right entry may resolve as -1 when measured as part of its row, but as +1 when measured as part of a column. This actually illustrates a fundamental principle of quantum mechanics called contextuality. It is now possible for the two players to assign the same states to their two qubits for all nine grid elements without any contradiction, while still obeying the rules.

So far, the two players can only win all nine rounds if they make lucky guesses about what each other will do. But there is a way to ensure success – this is where quantum pseudotelepathy comes in. The rules may forbid players from conferring, but they don't rule out entangling the players' qubits. If we did this, it means that the qubits can effectively share information, so that the state of one affects the state of the other. Set this up just right and, though the players don't confer, the qubits themselves will influence each other so that they snap into just the right state to win every time.

After all that mental exertion, I think I will be ready for my turkey. And perhaps after dinner I should give my kids a fair shot at winning. Anyone for a game of Exploding Quantum Kittens? ▮

Philip Ball is in it to win it

> **"With quantum rules, there is much more room for cunning strategy"**



CIRCA IMAGES/GLASSHOUSE IMAGES/ALAMY

What a wreck!

Jeremy Hsu explores how a sunken warship became an unlikely template for marine conservation

ON Christmas Day 1862, during the height of the US civil war, the crew of the ironclad warship the USS Monitor sat down to a decadent dinner. On the menu was turkey, mashed potatoes, plum pudding and fruitcake – rare treats for the sailors who had spent months subsisting on mostly crackers and salted pork. But events were about to take a less festive turn.

A few days after the meal, the ship set out to join a military expedition down the east coast. One evening, as darkness fell, sleet and snow blew in sideways and the ship rode a rollercoaster of 9-metre-high waves. It took on water and, before long, came to a sorry end at the bottom of the Atlantic Ocean.

If things had ended there, the Monitor would only be remembered by military historians. But that wasn't the final chapter of its story. More than a century after it sank, the shipwreck became entangled in the politics of marine conservation and, in an unlikely twist, has ended up serving as a test bed for a new way to save the seas.

In its day, the Monitor was a state-of-the-art vessel. Designed by Swedish-American immigrant John Ericsson and built in a steelyard in Brooklyn, New York, in 1861, the ship had an innovative gun turret, the first of its kind to revolve. After being rushed into battle against the Confederate forces of the slave-holding southern states during the civil war, the Monitor defended a squadron of five wooden frigates against a Confederate ironclad near Hampton Roads, Virginia, in March 1862. "That was the first time that steam-powered ironclads [had fought] each other," says historian John Quarstein, director emeritus of the USS Monitor Center. "It helped change naval warfare forever." The duel even inspired leading naval powers of the time such as Great Britain and France to switch from wooden warships to iron ones.

Despite its high-tech armoury, the Monitor had its flaws. While its low-to-the-water profile served it well in battle, it was best suited for patrolling calm coastal waters and rivers rather than braving the high seas. "It almost sank two [other] times," says Quarstein. In its final battle against the waves, 49 of the crew survived by reaching a nearby steamship. But 16 men were lost when the ironclad finally sank in the sea off North Carolina. It lay at the bottom, mostly forgotten, for decades.

In the early 1970s, scientists had been using sonar images to sift through shipwrecks in the so-called "graveyard of the Atlantic". They found 22 other wrecks before identifying the

PH1(AW/NAC) MARTIN MADDOCK, USN

Crew on board the USS Monitor in 1862 (far left); the warship's innovative gun turret, which was recovered in 2002 (left); the sunken remains of the vessel, now acting as an oasis for marine life (below)

Monitor, lying upside down on the sandy seafloor. Its iconic turret had separated from the main hull, but remarkably the ship's remains were mostly intact.

Upon finding a wreck of such historical importance, Walter Jones, congressman for North Carolina, was concerned. The US Navy had abandoned its legal ownership of the Monitor, which meant that, potentially, others could dive to the wreck and take away pieces of this valuable heritage. Luckily, the research team had discovered the ship at a fortuitous moment. Just one year earlier, in 1972, the US Congress had passed a new law allowing the creation of marine protected areas.

The Marine Protection, Research, and Sanctuaries Act empowered the government to designate coastal waters as national marine sanctuaries. These are places that typically are off-limits for the dumping of toxic materials or for polluting oil and gas exploration that taint waters elsewhere. But the Sanctuaries Act doesn't ban all human activities that could harm the ecosystems: each sanctuary has a unique set of regulations.

In January 1975, after a long campaign by Jones, an area 1.6 kilometres in diameter around the Monitor became the first marine sanctuary in the US. The rules were strict – prohibiting the destructive fishing practice of bottom trawling and requiring permits for any diving activity. "They don't want people to mess with the ship," says marine biologist Lance Morgan, president of the Marine Conservation Institute in Seattle. "So they keep activity, including fishing, away from it."

Since then, the patchwork of protected areas has grown into the national marine sanctuary programme, a network of 15 reserves covering some 1.6 million square kilometres of ocean and Great Lakes waters. These sanctuaries encompass not only any shipwrecks within them, including more than 130 wooden schooners and steel steamships, but diverse ecosystems that include coral reefs, islands, coastal waters and deep ocean canyons.

Now, there are calls for the protection to go much further. In response to the declining health of the oceans, a movement of scientists and governments has set an ambitious target of protecting 30 per cent of the oceans by 2030, known as "30 by 30". In December 2021, US president Joe Biden cited the national marine sanctuary programme as a crucial tool for making it happen in the US. So far, under Biden's incumbency, the National Oceanic and Atmospheric Administration (NOAA) has proposed two new sanctuaries: the Chumash Heritage National Marine Sanctuary off the coast of California and a new Hudson Canyon National Marine Sanctuary to protect the largest underwater canyon along the US Atlantic coast.

Unsafe havens

The US has established protected areas across 26 per cent of its water. Almost all of those are Marine National Monuments, created under a totally different law to sanctuaries, which offer a similar type of protection. However, beyond the marine monuments, the vast majority of US waters still have no high-level protection from fishing and other human impacts.

And just because an area is classified as a "marine protected" area doesn't mean we are doing enough. "There's still a gap between what the name of the statute implies and the reality out on the water," says Dave Owen, a professor of environmental law at the University of California. Almost all sanctuaries ban oil, gas and mineral exploration, but many still allow fishing. Some even permit the deeply destructive practice of bottom trawling.

Despite the challenges, experts still believe national marine sanctuaries are the best bet for protecting the seas. "When the programme was originally built, they thought of it as a few iconic places that they'll do their best to manage and protect," says Morgan. "Now that we recognise there's a lot of things eating away at the biodiversity in the fabric of marine life, it would be great if some of these areas were actually regeneration zones in the ocean." The hope is that these areas could become places for life not just to survive, but to flourish.

NOAA

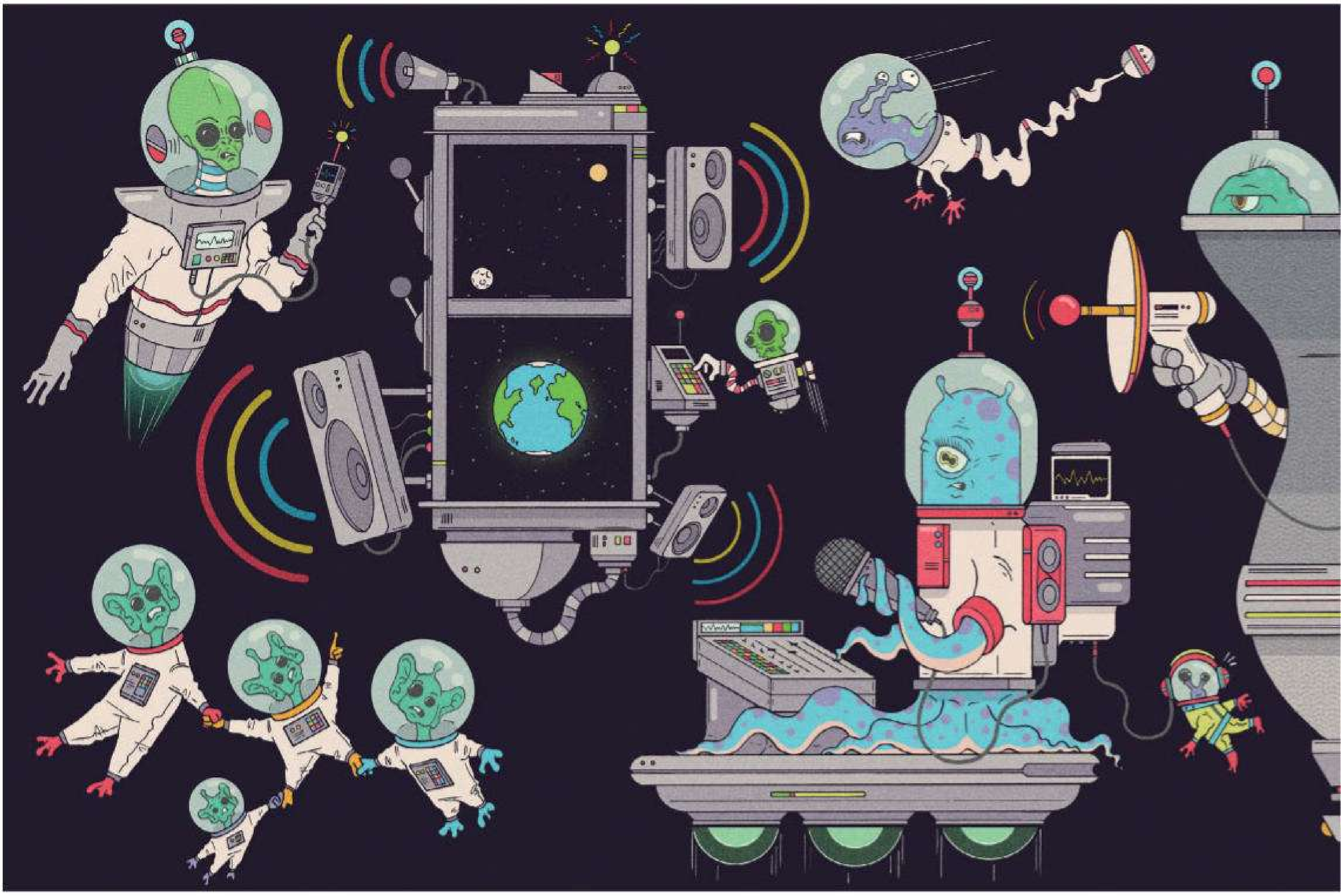
As for the Monitor, there has been some success. In May 2022, a NOAA research project sent a remotely operated underwater vehicle to the ship's resting place to conduct a survey, the first of its kind there in 20 years. The vehicle initially descended to the sea floor several hundred metres from the wreck before navigating towards the Monitor. As it got closer, the camera showed more and more fish swimming around the vicinity even before the vessel's iron hull became visible.

Swarms of small, silvery bait fish swim around the wreck, pursued by larger jack fish, while bigger predators such as grouper and snapper fish spend their time closer to the bottom of the structure. Brightly coloured tropical reef fish shelter among the Monitor's crevices and large groups of sand tiger sharks circle the wreck.

Despite being the smallest marine sanctuary, the Monitor has become a refuge for marine life. These protected areas are doing the business, then, says Beth Pike, director of the Marine Conservation Institute. "They just have to be well designed and well enforced."

The designers of this innovative warship would probably have preferred if it had spent a little more of its life above the waves. But at least in a sense, the story of the Monitor does have a happy ending. ▮

Jeremy Hsu's favourite holiday board game is Battleship



KYLE ELLINGSON

Hello, space alien

We have been sending messages to other galaxies for decades. What are we trying to say, asks **Abigail Beall**

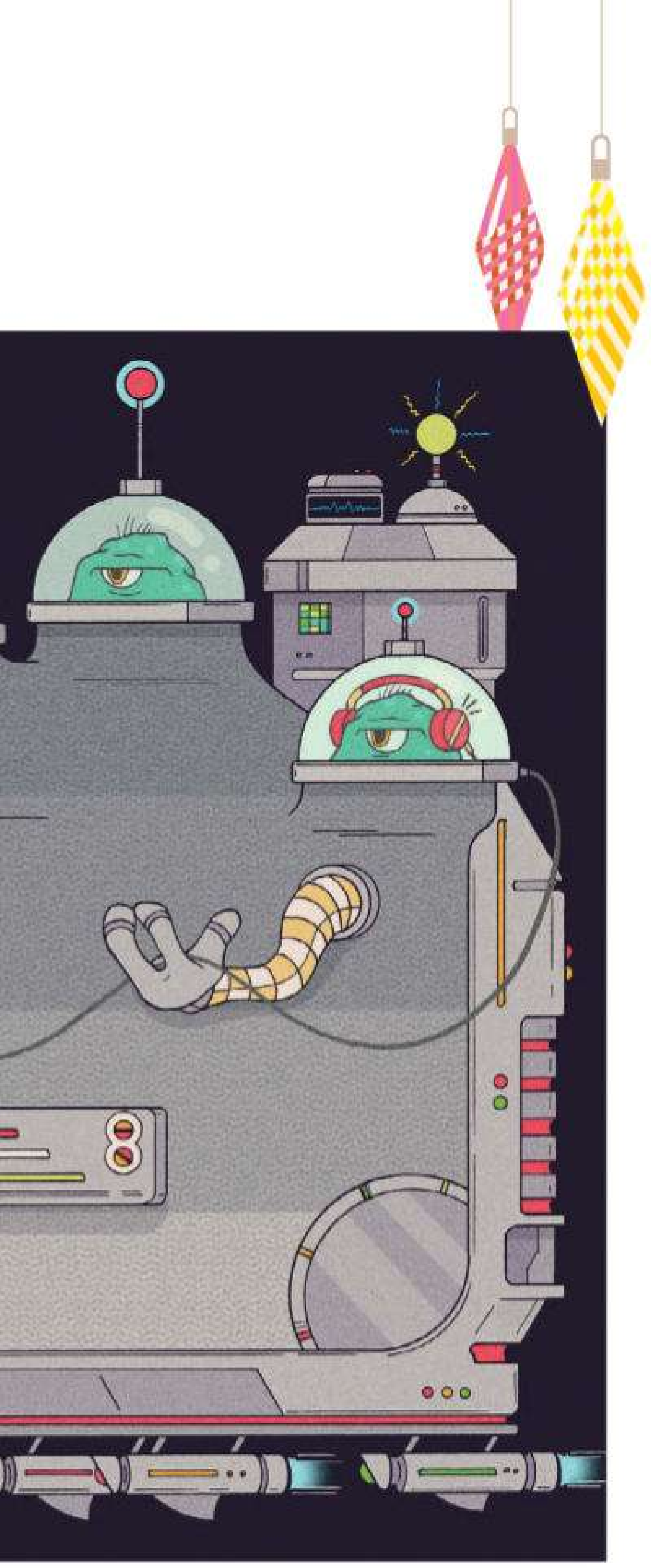
WHEN Jonathan Jiang was a child, his father told him about a group of astronomers using a huge telescope to send a message into space, in the hope that aliens in some far-flung galaxy would hear it. "They shouldn't do that," Jiang remembers his dad saying. "The contents should be approved by the citizens of the Earth."

The message, broadcast in 1974 from the Arecibo Telescope in Puerto Rico, was headed for a cluster of stars in a galaxy called Messier 13, or M13. It will arrive in just under 25,000 years – though, of course, we don't actually know if there are aliens there.

What we do know is that most stars in our galaxy host planets, and that many of these are potentially habitable. This means there is a chance that at least one of those billions of planets is home to intelligent life. Those odds are sufficient to suggest we should try to say hello. Or at least that is the rationale for sending targeted radio signals into space.

Over the past few decades, we have broadcast a mixed bag of signals, ranging from serious attempts to communicate with extraterrestrial civilisations to accidental broadcasts and daft publicity stunts. Put together, it makes for a slightly odd representation of us Earthlings. Given how much more we now know about the cosmos beyond our solar system, astronomers like Jiang, who works at NASA's Jet Propulsion Lab in Pasadena, California, think it is time we beamed a new postcard to the stars.

You could say we have been broadcasting our presence to space since commercial radio began in the 1920s. Radio messages are sent in a particular direction, but they tend to be sent in large beams, which leak out into the universe. They travel at the speed of light, which means one of the first signals any intelligent life within 100 light years of Earth could have heard is the results of the 1920 US presidential election broadcast by a manufacturing company in



Pittsburgh, Pennsylvania. By the 1950s, TV was also leaking out into the cosmos. "Our early TV shows have so far gone past about 10,000 stars," says Dan Werthimer, a radio astronomer at the University of California, Berkeley. "The nearby stars have seen *The Simpsons*."

In 1962, Soviet scientists deliberately transmitted three words, in Morse code, towards Venus: *mir*, which means peace in Russian, "Lenin" and "USSR". The next attempt, the one Jiang heard about as a child, was more ambitious. In 1974, astronomers led by Frank Drake at the Green Bank Observatory in West Virginia sent the first deliberate transmission to declare our presence to an alien civilisation from the Arecibo radio telescope. Known as the Arecibo message, it was directed towards M13, which contains 300,000 stars and, astronomers guessed, at least as many planets. "At the time, the only planets we knew of were in the solar system," says Jiang.

> **"After a few drinks, a pair of astronomers fired off the word 'cheers'"**

If there is intelligent life there to receive it, they will be faced with 73 lines of binary code, each with 23 characters. Decoded, it amounts to a grid of squares depicting the double helix of DNA above a stick drawing of a human and some numbers, including 4 billion, which was the human population at the time. There was also a map of the solar system, with Earth to one side, and a depiction of the Arecibo telescope. The idea was that any aliens able to receive the message could understand a bit about Earth and the intelligent life there.

The messages we have sent since have been more haphazard. In 1983, after a few drinks, a pair of astronomers at the University of Tokyo, Hisashi Hirabayashi and Masaki Morimoto, fired off a message that included the chemical symbol for ethanol and the word "cheers" in the direction of the star Altair. It is unlikely to have made its way to intelligent life, says Hirabayashi. "I don't think that the signal was received."

Klingon opera

Then came a barrage of cultural and commercial morsels. In 2008, NASA transmitted the song *Across the Universe* by The Beatles towards Polaris, also known as the North Star, while the University of Leicester in the UK worked with crisp brand Doritos to send a 30-second advert towards the constellation Ursa Major. That same year, a high-powered radio signal was sent towards Gliese 581c, a star 20 light years away that is known to have a super-Earth planet orbiting it. This signal contained 501 messages, each selected through a competition on the now defunct social network Bebo. In 2010, a Klingon opera was beamed towards Arcturus, the brightest star in the constellation Boötes.

All of which was a bit of fun and would arguably offer a reasonable, if decidedly partial, insight into Western civilisation – pop music, junk food, social media. But if we are serious about reaching out to possible extraterrestrial civilisations, we can surely do better.

That is certainly Jiang's feeling. He has been working with colleagues around the world to create an updated version of the Arecibo message that would be easier for aliens to decipher. It uses observations about the universe around us, assuming aliens would also observe the cosmos. To let them know where the signal is coming from, for example, the researchers created a map of the Milky Way using bright, tightly packed groups of stars called globular clusters as coordinates. To give an idea of the concept of time, they created a measure of time based on the frequency of a hydrogen atom and used the cosmic microwave background, the leftover radiation from the big bang, as the clock's first tick.

The Pioneer plaques, a pair of engraved plaques sent out into space attached to both the Pioneer 10 and Pioneer 11 spacecraft, included a man waving while a woman was just standing by. In the updated Arecibo message, both a man and a woman are raising their hands. "We want it to reflect the equity of man and woman," says Jiang. Like the original communication, the updated message shows the structure of DNA, but it also includes a map of Earth, showing the molecules in our land, oceans and air. It ends with a return address, which shows the position of Earth within the globular cluster and a time stamp of when the signal was sent. "We want them to reply," says Jiang.

Then again, many astronomers wonder if we should be sending signals at all. "We know very little about what's out there, and nothing about our universe's other inhabitants," says Werithmer. At a meeting 15 years ago, 98 per cent of 200 astronomers surveyed said messaging extraterrestrial life was potentially dangerous. If aliens learned that Earth contained an element they needed, would they decide to grind our planet to dust to access it? "We should be listening at first," says Werithmer, "learning more about the universe and its inhabitants."

Jiang and his colleagues published the final draft of their message in March 2022, but there are no plans to broadcast it yet. In principle, anyone with access to a powerful radio telescope could send it out. Ultimately, however, Jiang says that anyone thinking about broadcasting to alien civilisations should first consult the United Nations. Just as his father told him all those years ago, "it is not one group's statement, or even one country's", he says. "It has to truly represent the citizens of the Earth." ∎

Abigail Beall is shouting into the void

Memories on magnetic tape

We are generating stupendous amounts of data and much of it is stored in a surprising way, discovers **Becca Caddy**

GOOGLE/SHUTTERSTOCK

GETTY IMAGES

Right: A magnetic-tape drive in an office computer in the mid-1970s. Left: Magnetic storage tapes at a Google data centre today

WE HUMANS are hoarders. We love to amass information. And these days, with digital storage at our fingertips, we stockpile ludicrous amounts of the stuff, whether it is on hard drives at home or in the cloud. You might be surprised to discover, however, that a hefty chunk of the information we are holding on to today – from backups of your emails and photos to particle collision data from the Large Hadron Collider – is stored not on sleek hard drives, but on clunky plastic cartridges containing coiled ribbons of magnetic tape.

That's right, much of the world's data is stored on tape – many thousands of kilometres of the stuff. While that may induce nostalgia for those who are old enough to remember making mixtapes and recording songs off the radio to cassette, tape technology has advanced enormously. So much so that researchers today are increasing its storage capacity at a rate that outstrips its rivals.

Even tape has its limits, though. We are generating so much data that eventually it will be impossible to store everything. Then what?

To be clear, the tape we are talking about here isn't quite the same as the cassettes that were once stacked high in the bedrooms of children of the 1980s, even if it is basically the same technology. The difference is that old-fashioned cassette tape is analogue, whereas the version used for data storage today is digital – meaning the information is stored in zeroes and ones.

When IBM brought the first commercial digital tape storage system to market in 1952, it could store 2 megabytes of data on one large reel. Today, its tapes are much smaller and yet they hold 20 terabytes of data, or 60 terabytes in a compressed format – increasing capacity by about 10 million-fold in 70 years. A single cartridge can hold more than a kilometre of digital tape, and the cartridges are stored in automated libraries, the largest of which can hold up to 23,000 of them.

To access the data, robots move back and forth on rails through the racks of cartridges. They work impressively fast, but it still takes 90 seconds for a robot to find the cartridge, remove the tape, put it on a drive and find the data on the reel, whereas a hard drive can retrieve your information in 10 milliseconds. Which is part of the reason why hard drives have long dominated data storage.

Then again, not all data needs to be retrieved at lightning speeds. From satellite imagery and surveillance camera footage to countless backups of your emails, tweets and financial records, archival data is known in the trade as "cold" data. Digital tape has survived and thrived as a means to store it because it offers several advantages over hard drives.

For starters, tape is secure and reliable. If it isn't in use, it is safely tucked away inside its cartridge, disconnected from the internet, offering a robust defence against any errors or faults in computer programs, as well as cyberattacks. "If the cartridge isn't mounted into a drive, no one can modify the data," says IBM scientist Mark Lantz. In 2011, a software bug deleted emails from 40,000 Gmail accounts and affected data copies stored on hard drives. Luckily, Google had backed up the emails to digital tape and people's accounts could be restored.

Most importantly, tape is cheap – which is appealing for what Lantz calls "hyper-scale cloud companies" like Microsoft Azure, Google and Meta. This is mostly backups of stuff like your inbox and your endless photos of your dog, as well as things like smart home security recordings, analytics, manufacturing

A CASSETTE COMEBACK

As digital tape maintains its place as the hottest tech in "cold" data storage (see main story), old-fashioned music cassette tapes are seeing a revival. According to the British Phonographic Industry, 185,000 cassette tapes were sold in the UK in 2021, a 19 per cent increase from 2020 and the highest total since 2003. More artists, including Olivia Rodrigo and Billie Eilish, are now releasing music on tapes.

But audio on cassette doesn't sound as good as hi-res streaming, so what is the appeal? Well, it is the same reason vinyl has made a comeback – the enduring lure of retro technology. Earlier this year, a series of experiments carried out by a team including psychologist Matthew Fisher at Yale University showed that people tend to prefer technology they think was invented before they were born, an effect that holds even when the technology isn't as old as people think.

For some, it is also about leaving a physical legacy. "It's for the novelty, but also the archival nature," says Cal King from London, who has recently started buying music tapes. "Nobody will go through my Spotify playlists when I die, but they'll have boxes of my cassettes."

logs and myriad other stuff besides.

In the past, to meet growing demand for data storage, these companies would just buy more hard drives. But the capacity of hard drives isn't growing fast enough to keep up because they only have a limited amount of room to write data.

Age of the zettabyte

Magnetic tape is different. "We have a kilometre of tape, a huge surface area," says Lantz. "We can keep scaling the technology." They do it by shrinking the parts of a drive that can retrieve and record data, so that smaller bits of information can be recorded on the tape. You can think of it as the difference between using a thick marker pen to write on an A4 sheet of paper and using a fineliner on an A3 sheet. As a result, tape's storage capacity continues to grow and that will carry on for a while yet. "We can keep scaling tape and doubling the capacity every two and a half years for at least 20 more years," says Lantz.

For all its retro prowess, however, tape will also run out of space one day. We are producing more data than we can store. To grasp just how much, consider the zettabyte – roughly equivalent to 250 billion DVDs. In 2020, we produced some 59 zettabytes of data; projections suggest that by 2025 we will be generating 175 zettabytes every year. "It'll reach a point where the entire planetary mass would have to be some form of digital data storage or programmable matter in order to sustain the digitisation of the world," says Melvin Vopson at the University of Portsmouth, UK.

We are going to need new technologies, he says. Researchers are exploring the possibilities of storing data with photons and DNA. One of the most intriguing solutions, however, is using lasers to encode data into silica glass by creating nanostructures that a microscope can read. Peter Kazansky at the University of Southampton, UK, who has already worked with Microsoft to design a silica-based storage system, says the data becomes "virtually eternal" because silica glass is resilient to pretty much everything, from extreme temperatures and moisture to magnetism and radiation. It is thought to remain stable at room temperature for 300 billion billion years, which means it could guard our precious data long after the sun dies.

We just have to hope that whoever finds the glass has the technology to discover what is inside – and an interest in the minutiae of our old social media posts and cat pictures. ▮

Becca Caddy is determined not to become an obsolete technology

The mother of all sprouts

The origins of this most divisive vegetable have been a mystery, but we are approaching an answer, finds **Claire Ainsworth**

RUBY FRESSON

“I STUDY the dogs of the plant world.” That is the answer you will get if you ask Chris Pires what he does for a living. He will tell you that dogs, despite their dazzling diversity, are all members of a single species – and that the plant species he studies has its own equivalents of pugs, Labradors and Great Danes. He will then recount his odyssey to find this plant’s closest living wild relative – its equivalent of the wolf – to learn how it came to be tamed. It is a tale of Greek gods, island giants and ancient antidotes to intoxication.

Having heard it, you will never see Brussels sprouts in quite the same way. Often overcooked and under-loved, you wouldn’t expect this Christmas stalwart to have an exotic backstory. But the other dishes in your festive spread reveal why it is so fascinating. Whether you are eating cauliflower, Savoy cabbage, broccoli, kale, collard greens or even kohlrabi, all these vegetables belong to a single species: *Brassica oleracea*.

Just how you can get such variety from one plant has intrigued scientists, including Charles Darwin, for centuries. It makes *B. oleracea* a fantastic way to study the power of selective breeding. “Domestication in general is fascinating because it’s like fast evolution,” says Pires, an evolutionary botanist at the University of Missouri. And solving this conundrum could help create new crops that are resistant to climate change.

B. oleracea is the species name of at least 16 different vegetables that come in an incredible range of forms, from the bite-sized Brussels sprout to the giant Jersey cabbage, native to the Channel Islands, which grows into a sort of tree that can be up to 4 metres tall. They were all created by humans over millennia. “Our story

“In Greek legend, cabbages sprung up where Zeus’s sweat fell”

is entangled with this one species of plant,” says Makenzie Mabry at the University of Florida. Yet efforts to pin down the identity of its ancestor have proved frustrating.

Weedy, cabbage-like plants are found growing wild along the Atlantic coastline of Europe, and one idea is that *B. oleracea* was formed by the domestication of these in England. Another hypothesis has it that the Mediterranean, with its vast diversity of cabbages and kales, is the species’ birthplace. Adding to the mystery is the fact that the family tree of *B. oleracea* vegetables and their relatives is more like a tangled, bushy shrub. That has left researchers struggling to decide how many domestication events the plant has undergone and how many ancestors it had.

To try to settle the matter, Mabry, Pires and their colleagues drew on evidence from a variety of sources. First, they turned to the *B. oleracea* genome, and compared the DNA of 14 of these vegetables and nine wild cabbages. By looking for similarities at specific points in the genomes, they grouped the plants together to understand their evolutionary relationships. This pointed to a weedy-looking plant called *Brassica cretica* being *B. oleracea*’s closest living wild relative. This suggests it could be the wild ancestor of *B. oleracea*, or very closely related to it, with domestication first occurring around 4200 years ago. *B. cretica* suns itself on the shores of the Aegean Sea, lending weight to the Mediterranean hypothesis.

The Aegean location is consistent with a study of ancient texts by Lorenzo Maggioni at Bioversity International in Rome, Italy, and his colleagues. The earliest mentions of *B. oleracea* vegetables are in Greek literature dating from around 2500 years ago. These include advice from the botanist Theophrastus to use the plant to ameliorate the intoxicating effects of alcohol – a myth that persists in parts of southern Italy, says Maggioni. Later, Roman writers describe an explosion of different kinds of *B. oleracea*, including large-headed cabbages, which weren’t to everyone’s taste. “Pliny even says he was dismayed by seeing these ‘monstrosities’ coming to the market – as if they were the [genetically modified organisms] of the time,” says Maggioni. Such testimonies of the use and diversity of *B. oleracea* don’t appear in ancient texts from other areas, he adds.

Mabry and Pires’s independent study of cultural sources came up with the same answer. What’s more, the habitat in the eastern Mediterranean would have suited *B. cretica*, according to a reconstruction of its Late Holocene ecology by Alex McAlvay at New York Botanical Garden. It did indeed look as though *B. cretica* could be the ancestor, and that the Eastern Mediterranean was where humans began to domesticate it – very apt given the Greek legend that cabbages sprung up where Zeus’s sweat fell to the ground.

Feral cabbages

These results are broadly confirmed by another genetic study, published this year. The team, led by Guusje Bonnema at Wageningen University in the Netherlands, found that domestication occurred around 4600 years ago in the Middle East. “It’s very close,” says Bonnema. However, the researchers didn’t confirm *B. cretica* as an ancestor, partly because they didn’t set out to identify one.

So there are still a few loose ends to tie up. Mabry and Pires were unable to sample Atlantic wild-growing cabbages in their genetic analysis. They think these are likely to be feral plants, ones that were cultivated but now grow wild, but they don’t know for sure. “Until there is a confirmation that all the Atlantic plants are not wild, then there is a margin of uncertainty,” says Maggioni. What’s more, there are signs that some of the *B. cretica* plants Mabry and Pires tested are feral, not wild, hinting that *B. cretica* itself was domesticated at one point.

This complicates the picture, but it also strengthens the possibility that feral plants played a pivotal role in *B. oleracea*’s domestication – perhaps lurking on the fringes of cultivated fields and adding their genes into the mix. Feral plants could be crucial to the species’ future, too. Let off the leash, cultivated varieties adapt to local conditions, forming a pool of variation that scientists could draw on to produce vegetables that are better suited to a warmer world. If a feral plant is resistant to herbivores or drought, those genes could be added back in using gene editing, or the plant itself could be re-domesticated.

The next step for Pires and Mabry is to visit, collect and conserve as many wild-growing *B. oleracea* as possible, including Atlantic wild-growing cabbages. Meanwhile, the sprouts on your Christmas platter continue to evolve as our tastes change. Modern strains have been bred to replace the bitterness with a sweet, buttery flavour. So if you are an inveterate sprout-hater, give them another try. Just don’t boil them to a mush first. ▮

Claire Ainsworth is looking forward to a brassica bonanza

SHUTTERSTOCK/KOSTENKO MAXIM

Self-compassion isn't selfish. It puts you in a better position to help others, says **Claudia Hammond**

THIS season is, of course, a time of goodwill to all. It is about giving – offering gifts to your nearest and dearest, making food for family and friends and perhaps donating to a charity that is helping people in a less fortunate position. But it can also be a time when you set yourself high standards. Any old meal won't do, it needs to be amazing and so do the nibbles, and the wine, and the tree. Your efforts to give everyone else a good time can leave you feeling frazzled.

So, how about a little goodwill to ourselves? I am not talking about self-indulgence and self-obsession, but self-compassion. It doesn't mean deciding that you are always great and never wrong. It means accepting that you are human and that, like everyone, you do your best but sometimes make mistakes. Recent research shows that self-compassion is essential for our mental health and, as I explain in my new book *The Keys to Kindness*, it is far from selfish because it can leave you in a better position to be kind to others.

Scientists have various methods of measuring self-criticism and self-compassion, but most revolve around self-report scales. As an example, consider the following statements. Do any of them ring true for you?

"I fear that if I become kinder to and less critical of myself my standards will drop."

"Getting on in life is about being tough rather than compassionate."

"When I try to feel kind and warm to myself I just feel kind of empty."

These statements are part of a psychological scale devised by Paul Gilbert at the University of Derby, UK, who is a leading authority on shame and compassion. If you agree strongly with all three statements, you may fear being kind to yourself and favour self-criticism (though you would need to read and rate the full set of statements to be sure).

The consequences of too much self-criticism and too little self-compassion can be serious. In one study, Mark Leary at Duke University in Durham, North Carolina, and his colleagues emailed participants several times over a three-week period, asking them about the worst thing that had happened to them in the past four days and whether it was their fault. They found that people with low self-compassion tended to find it harder to put everyday setbacks into perspective. In another study, Leary's team found they were also much more sensitive to other people's feedback.

A lack of self-compassion may be a particular problem for people with depression. Excessive self-criticism both puts people at a higher risk of developing the condition in the first place and then contributes to a downward spiral into despair and hopelessness. According to Gilbert's research, knowing if people are very self-critical can predict more than a third of cases of depression, while various other studies show that people with higher levels of self-compassion tend to have fewer mental health difficulties.

Levels of self-compassion even made a difference to how people managed at the start of the pandemic. An international team of researchers, including Gilbert, conducted interviews with 4000 people in 21 countries during April and May 2020, when many of the participants were living through lockdowns. In every country studied, people who feared self-compassion scored higher on measures of depression, anxiety and stress.

Kindest in class

So, a little self-kindness is in order, but is there a risk of becoming self-indulgent and overly focused on yourself?

The research suggests we need not worry too much. Consider one study from Australia, which followed 2000 teenagers through their last three years of school, while regularly measuring their levels of self-compassion and empathy with questionnaires. Each student was also asked to name privately the three girls and the three boys in their English class who were always ready to lend a helping hand. This allowed the team to rank the students in order of how kind other students considered them to be. The importance of self-kindness was clear. The higher the students' scores on "kindness to themselves", the higher their scores on empathy towards others and the more likely they were to have made it onto the kind classmate list.

This doesn't mean that you have to be kind to yourself in order to be kind to others, but Gilbert's studies also show that people with high levels of self-kindness are more likely to apologise if they behave badly. Tellingly, Gilbert's investigations show that people with greater self-compassion tend to report having better relationships than those who lack it, too.

> **"For the overly self-critical, all is not lost. Self-compassion can be cultivated"**

You might also wonder if self-compassion encourages laziness, or prevents you from learning from your mistakes, but this doesn't seem to be the case. Researchers at Carleton University in Ottawa, Canada, asked a group of students whether they delayed studying for an exam until the last minute. Had they done less important things when they could have been revising? Unsurprisingly, the procrastinators didn't tend to do that well on the exam in question. But if they forgave themselves for their mistakes, they were more likely to study harder for the next test than those who had beaten themselves up about it.

If you are overly self-critical, all is not lost, because the psychological research shows that self-compassion can be cultivated. One technique that can be useful if you are struggling is to write a compassionate letter to yourself – a strategy that Leary and his colleagues have tested.

To do so, he and his team first asked participants to think of a negative event from their past that had made them feel bad about themselves and then, bearing that in mind, to list the ways in which other people may have experienced similar events. This was to prompt feelings of shared humanity. The participants were then asked to write a paragraph expressing understanding, kindness and concern to themselves in the way they might write to a friend who had experienced what they had been through.

DAVID TROOD/GETTY IMAGES

Giving to others can be a heavy load if we don't pause to look after ourselves

Afterwards, those participants who completed the exercises experienced fewer negative emotions about the event than those who wrote about their own positive characteristics and tried to explain why the event wasn't their fault, and another control group who didn't write anything at all. Those who did the exercises continued to think that they were the type of person who bad things happened to, and they still felt they had made a real mistake – but the important difference was that they stopped hating themselves for it.

Another, more involved, programme comes from Kristin Neff at the University of Texas at Austin and Christopher Germer, a clinical psychologist at Harvard Medical School. Their Mindful Self-Compassion programme involves eight, weekly workshops. As the name suggests, the participants learn mindfulness skills and practical techniques for treating themselves with more caring concern. Contrary to the idea that self-compassion encourages self-obsession, the participants are encouraged to place their troubles in a wider perspective and to recognise the suffering of others. (You typically have to pay to attend a course, though free resources are available from Neff's website.)

The results are striking. One study by Neff and Germer found that people's levels of mindfulness, self-compassion, life satisfaction and happiness rose significantly during the course, and their feelings of depression, anxiety and stress dropped, compared with a group of people who hadn't yet attended the course. You might suppose that, after a few weeks, people would go back to their old habits and start blaming themselves again. But no: a year after the course, the pair found that the gains remained.

So, if you host Christmas and the turkey is drier than you would like, the pudding doesn't come out quite right and people don't want to play the games you have chosen, that is OK. You are only human and any imperfections are best forgiven and forgotten. ▮

Claudia Hammond is off for a nice bath and a hot chocolate. This article is based on a chapter of her latest book *The Keys to Kindness*

Meet Lazy Geoff

In animal tracking studies, there is often one individual that just sits around doing nothing for ages. How do they get away with it, wonders **Michael Marshall**

FOR Dani Rabaiotti, it all started with a study involving synthetic fox urine. The plan was to see if the stuff affected a fox's territorial behaviour. Unfortunately, the study was a bust because the fox that was selected did almost nothing. For the entire three-month tracking period, it sat under a shed, leaving only twice: once to lead them "all around the houses", and once to briefly nip into a neighbouring garden.

Rabaiotti, now at the Institute of Zoology in London, was reminded of that fox earlier this year, when the GPS signal from an African wild dog in Kenya that she was tracking suddenly stopped moving. Obviously, the animal might have died. But she was intrigued by an alternative explanation. Maybe, she thought, the wild dog had "just decided to sit still".

She turned to Twitter: "My favourite thing is when people stick trackers on animals and one does literally nothing interesting and sits in 1 place 99% of the time and the researchers are like oh yeah that weird datapoint is Lazy Geoff, he doesn't ever do anything for reasons we don't entirely understand."

Soon, other researchers chimed in. "Definitely tracks with one of the leopard cats I became familiar with in Borneo"; "Dudley the juvenile male Steller sea lion was a stand out!" For a brief period in March, #LazyGeoff trended on Twitter. But why do some animals move so little? While answering the question is difficult, we are getting some helpful hints – and it turns out that acknowledging the existence of Lazy Geoffs could be vital for anyone studying animal behaviour.

There is no shortage of animals that seemingly do nothing. Although sloths are famous for it, they aren't alone. Take the olm, a kind of salamander that lives in European caves. A few years ago, researchers found one in exactly the same spot they had last seen it in seven years earlier – though it might have budged while they weren't looking.

But we can understand why these animals don't move much. Sloths have adapted to eat poor-quality food that takes months to digest, while olms are "sit-and-wait" predators that target crustaceans that are rare in the olms' caves. In circumstances like this, it makes sense to move slowly or not at all.

Lazy Geoffs are different: they are animals that should move, but don't. Sometimes, there is a prosaic explanation. For instance, it turned out that Rabaiotti's wild dog was still moving, but no longer transmitting a signal because of a flat battery in its GPS collar. But other Lazy Geoffs really do specialise in staying put. A study published earlier this year provided more confirmation of their existence. It analysed results from 41 tracking studies of various mammals, birds, reptiles, fish and amphibians, concluding that individual animals have unique movement patterns that are consistent over time.

Maybe personality type in a more general

> **"They found a salamander in exactly the same spot as seven years earlier"**

ADAM NICKEL

sense explains why some animals have so little get-up-and-go. Animal personality researchers have often focused on a handful of traits, such as how shy or bold they are, whether they prefer to explore or avoid a situation, and their aggressiveness – and there are hints that at least some of these might affect the amount they move.

For example, Benjamin Toscano at Trinity College in Connecticut and his colleagues have unpublished data on how snails respond to the risk of predators. "We take a snail and we tap it with tweezers and then we put it down in a cup," he says. When tapped, the snails retreat into their shells. "Then we just start a timer and say, how long does it take for that snail to come back out of the shell and resume its normal snail life?" Most emerge within tens of seconds, he says, but some hide for many minutes – indicating a preference to avoid rather than explore a situation.

"In humans, we've got these big five axes of behavioural variation," says Kimberley Mathot at the University of Alberta in Edmonton, Canada. They are openness, conscientiousness, extroversion, agreeableness and neuroticism. A person's scores across these five traits are meant to predict their behaviours.

It is tempting to think that inactive animals simply aren't conscientious: they don't move even though they know they ought to. However, Mathot says we can't make inferences about the cognitive processes underlying Lazy Geoff-like behaviour unless an experiment is explicitly designed to explore that – and none to date has been.

An alternative is that Lazy Geoffs owe their inactivity to physiology. Some animals have faster metabolisms than others, meaning they digest food at different rates and expend energy faster or slower. It seems plausible to imagine that animals with differing metabolic rates might differ in their activity levels.

However, the links between metabolism and activity levels are complicated, says Mathot. In 2018, she and her colleagues published an analysis of metabolic rate and activity, combining data from more than 8000 individual animals, including mammals, birds, reptiles and amphibians, that had been studied in more than 70 previously published analyses. Some behaviours, such as maximum running speed, did correlate with basal metabolic rate. But others, including levels of activity and exploration, showed no relationship.

Human influence

In fact, it turns out that, in at least some situations, Lazy Geoffs might owe their existence to our human-dominated world. A study published in 2018 compiled GPS tracking data for 803 individuals across 57 mammal species, including elephants, anteaters and baboons. It found that mammals living in areas with a high human footprint moved only one-third to one-half as much as those living in areas with a low human footprint.

The authors initially interpreted this as the result of negative impacts from roads or other barriers to movement. However, a follow-up study two years later suggested an alternative explanation. It found that animals in human-dominated landscapes tend to live at higher population densities and have smaller ranges. "It's because they get loads of food in cities and they don't need to go very far," says Rabaiotti. Her slothful fox may be an example of this. "It's quite common for people to feed foxes here [in the UK]," she says.

Rabaiotti thinks there is a lesson in all of this. When tracking animal behaviour, it is necessary to study a large sample so that the results aren't unduly influenced by the occasional Lazy Geoff. "There are a lot of animal movement studies out there where they only have one or two individuals," says Rabaiotti. "It's important to bear in mind that [those individuals] might just be a bit weird."

Are these animals genuinely lazy, though? "I googled the definition," says Mathot. "It's 'an unwillingness to expend energy'." That, she says, is a testable hypothesis. However, she says "lazy" is generally used as an insult, which is the wrong way to look at it. "My guess would be that if we looked at these animals, in a lot of cases they're going to be doing little because it's the right choice for them, and if they did more, it wouldn't have better payoffs."

Rabaiotti has a similar view, but she is nevertheless OK with the word. Barring some domestic dogs that were bred to be energetic, animals don't expend calories unless they have to, she says. "Most animals, at their heart, are lazy." ∎

Michael Marshall is looking forward to the prospect of sitting around doing absolutely nothing this week

The conquest of cold

As physicists have devised experiments to get ever closer to absolute zero, they have encountered reality getting very weird. Now, quantum fridges might break temperature itself, finds **Karmela Padavic-Callaghan**

TO IMAGINE working your way down the temperature scale into the realms of extreme cold, you might start with the inside of an industrial freezer. At about -18°C (0°F) , it is uncomfortable, but bearable with some warm clothes. Now, turn your mind to the -60°C (-76°F) or so that explorers experience during the Antarctic winter, a temperature so severe it can ruin human flesh. And then, for the ultimate in cold, think of space itself at -270°C.

Except, it might surprise you to hear that the coldest places in the universe aren't in space, but in the physics departments of many universities. Here, over the past few decades, researchers have been contriving ways to reach ever closer to the coldest possible temperature, absolute zero. In the process, we have entered a new realm where bizarre states of matter can flow uphill, chemical reactions can be paused and designer materials can be assembled.

Now, though, the conquest of cold is entering a new phase as we build the ultimate cooling technology: the quantum fridge. Power up one of these ultimate cooling machines, and things get stranger still, with heat flowing backwards and temperature itself ceasing to have any meaning.

The question of what it means for something to cool is thousands of years old. In 450 BC, the Greek philosopher Parmenides thought up *frigidum primum*, a hypothetical substance that was as cold as possible and could imbue other objects with coldness. In 1664, after a rigorous study of candidate substances like air or water, the chemist Robert Boyle declared the idea unjustifiable. He and his contemporaries instead believed that heat and cold were separate entities produced through chemistry or by living things.

Today, we understand that hot and cold are relative properties of a substance determined by how much its constituent atoms are jiggling around. If those atoms have lots of energy and are moving fast, it will be hotter than if they have less energy and are moving more slowly.

When it comes to how cold things can get there is a fundamental limit. In 1848, Lord Kelvin introduced the idea of absolute zero. This is the point at which the atoms in an object stop moving entirely and so can't get any colder. By extrapolating from experiments, Kelvin calculated that this point would be reached at -273°C. (In case you are wondering if there is a hottest possible temperature, there are physical limits – atoms can't move faster than the speed of light, for instance – but the specific number isn't known.)

In the decades that followed, Kelvin and others developed thermodynamics, the theory that relates heat, work and a quantity called entropy. Entropy is a measure of disorder. When atoms are zipping about chaotically, they are said to have high entropy, and when they are moving more slowly or just vibrating gently in neat patterns, they have lower entropy. We soon learned that heat always flows from warm to cold so that objects naturally reach equilibrium with their environment – think of a cool drink warming up in the summer sun – unless we put in some energy to push things the other way.

> **"Evaporative cooling uses lasers to shoot away all but the coldest of cold atoms"**

Freezers use energy to cool things down and high-end machines can usually only push this as far as -80°C (-112°F). But there is a relatively simple way to achieve a far lower temperature – pressurise some helium gas and expel it through a nozzle to create liquid helium at a temperature of -269°C, just 4 degrees above absolute zero. Immerse an object in this liquid and it will get very cold indeed.

How low can you go?

In the late 1980s, three physicists independently devised a way of getting even closer to absolute zero, and it would prove to have huge consequences. The researchers in question were Claude Cohen-Tannoudji at the École Normal Supérieure in Paris, Steven Chu, then at AT&T Bell Laboratories in New Jersey, and William Phillips at the National Institute for Standards and Technology in Maryland.

They started with a gas of atoms such as caesium or rubidium buzzing around in a vacuum chamber. The researchers then hit each atom with a laser pulse oriented the opposite way to the direction the particle was travelling in. By doing this many times, they could slow the atoms down to a hundred-millionth of their original speed, so that they were barely moving. And because heat equates to atomic movement, they were now very cold. The record was 40 microkelvin, just a few tens of millionths of a degree above absolute zero. In 1997, the researchers shared the Nobel prize in physics for inventing this cooling method.

In the early 1990s, three other physicists, Eric Cornell and Carl Wieman at the University of Colorado Boulder and, separately, Wolfgang Ketterle at the Massachusetts Institute of Technology, took yet another step down the temperature ladder. Their method, known as evaporative cooling, used lasers not just to slow atoms down, but also to shoot the

›

OLIVER BURSTON

warmest ones away, leaving only the coldest of the cold. They managed to cool rubidium and sodium atoms down to temperatures measured in nanokelvin, about a thousandth of the temperature achieved in the 80s. It won the trio a Nobel prize of their own in 2001.

All this allowed us to step through the door into the quantum world. It is a strange realm, where particles can sometimes exist in two places at once, or be entangled such that they can apparently influence each other instantaneously over vast distances. But these quantum behaviours can only be observed when the particles are undisturbed by outside influences, which includes even the vibrations of neighbouring atoms. With heat all but removed and the atoms now still, we could explore the quantum world freely.

One of the first things Ketterle and his colleagues discovered, in 1995, was a new state of matter that had been predicted by Albert Einstein 70 years before, but never observed. When you cool objects, you expect them to freeze into a solid. But hundreds of thousands of ultracold atoms can behave as a uniform chunk of quantum matter, known as a Bose-Einstein condensate. They lose their individual identity and slosh around as an odd liquid that can sometimes flow uphill. "As a general principle, if you can reach lower temperatures, you are bound to make discoveries," says Ketterle. "If you live in a desert, you could not discover ice unless you build a refrigerator. That's what we did when we reached nanokelvin temperatures."

Since then, these cooling methods have created the booming field of ultracold physics, and we have learned how to cool molecules as well as atoms. It isn't overstating it to say this has transformed physical science.

Press pause

Take the way we design materials. Say we want to create a superconductor, a material that conducts electricity with no resistance. In the past, scientists would find a material – a metal perhaps – that did the job reasonably well, then investigate its atomic structure so they could better understand what makes an exceptional conductor. But that is a tricky job because the inner workings of materials are so complex.

Ultracold physics allows a better approach. Scientists can take molecules that are almost motionless and join them together like building blocks, assembling a material from scratch. This allows them to easily test hypotheses about how the internal structure of materials dictates their properties. This approach helped us grasp that a quantum property of atoms called spin seems to play an important role in some types of superconductor, for example.

KARMELA PADAVIC-CALLAGHAN

The world's largest quantum computer fridge at IBM in the US hits a chilly 25 millikelvin

Chemistry has also seen dramatic advances. Laser cooling can be used to slow down and steer chemical reactions so researchers can watch with unprecedented precision and clarity how molecules combine or split. In 2019, for instance, Kang-Kuen Ni's research group at Harvard University cooled potassium and rubidium atoms to 500 nanokelvin, forced them to start reacting, then used a laser to halt the reaction halfway through its natural course. What they spied when they hit pause was an intermediate molecule that had never been seen at room temperature. By manipulating that frozen state with even more laser light, the researchers could effectively steer the rest of the reaction.

You might think that a billionth of a degree above absolute zero is as good as we can get. But lately researchers have been working on an entirely new cooling machine: the quantum fridge. This would be a system that employs the rules of the qauntum world to cool things down, and it could take us to a whole new frontier of cold – and weirdness.

Don't picture a quantum fridge as remotely like a kitchen refrigerator – you won't be putting your milk in one. Rather, they tend to consist of tiny quantum objects connected so that heat can be transferred from one to another. In 2019, Dzmitry Matsukevich at the National University of Singapore and his colleagues crafted such a quantum fridge out of three laser-cooled ytterbium atoms. "We could build a tiny machine, operate it in the quantum regime and see what happens," he says. They experimented with putting these atoms in quantum states, for example quantum entangling them. Some of these effects allowed the fridge to cool a particle down by more than should be allowed by the rules of thermodynamics.

In the same year, Eric Lutz and his colleagues at the University of Stuttgart in Germany made their own quantum fridge. Their design used molecules acting like the quantum bits, or qubits, in a quantum computer. The qubits were quantum correlated, meaning they could share information in a special way. Under these circumstances, the researchers showed that heat could flow the "wrong" way, so that a warm area would steal heat from a cooler area. The difference between the areas was minute, tens of billionths of a degree, but it was still a flagrant violation of the laws of thermodynamics.

For these quantum fridges, then, the normal rules clearly don't apply. In a sense, this is no surprise. Thermodynamics is a theory designed to deal with sizeable collections of particles. Entropy, or disorder – that property so intertwined with temperature – only makes sense for a group of particles. When we are dealing with a quantum system of, say, two or three almost motionless particles, it is far less clear what "entropy" or "temperature" means.

Ronnie Kosloff at the Hebrew University of Jerusalem thinks thermodynamics should really apply in all circumstances. But perhaps, he says, we need a new version of the theory – quantum thermodynamics – that uses a definition of temperature that works at a quantum level; then the behaviour of quantum fridges might make more sense. One promising option is to use information as a proxy for temperature. It is another quantity that is closely related to entropy, but one we understand fairly well at a quantum level.

Quantum thermodynamics remains a work in progress. And quantum fridges are still being refined. But one thing is becoming abundantly clear: when we reach the bottom of the temperature scale, heat and cold become far more slippery concepts. ∎

Karmela Padavic-Callaghan is the coolest customer on the block

A poo picture puzzle

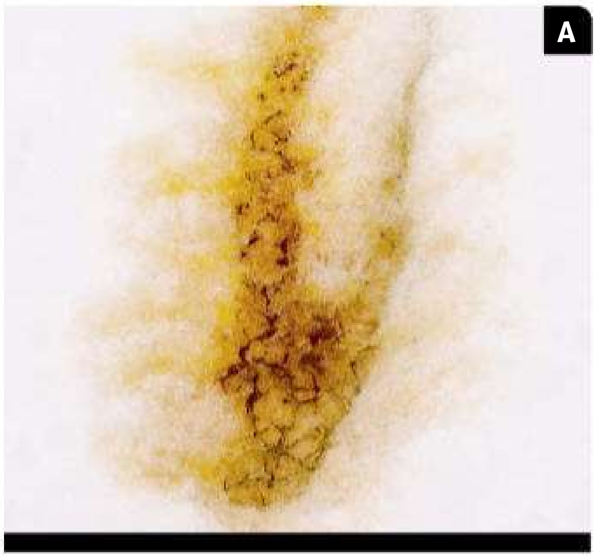
Animal faeces is more interesting than you might think. But can you tell your eagle excrement from your penguin poop? Test yourself with naturalist **Chris Packham**'s quiz

SPLATTED, splodged or squirted, strategically positioned or neatly coiled – a package of poop always comes with a message to be interpreted by the curious naturalist. At its simplest, it betrays which creature has been there. With practice, it will tell you much more. Under laboratory scrutiny, it tells us about the state and status of the individual, as well as information about the species as a whole that we may not otherwise know, such as its distribution, population and diet. It might sometimes be stinky, but excrement is always a font of knowledge. And at a time when every little thing counts in our struggle to save the world's species, we can't afford to turn our noses up at it. So let's learn to love animal poo – starting with this quiz.

Chris Packham is a naturalist, author and TV presenter who really knows his shit

How to play

Take a look at the six photographs below and try to guess which animal left which specimen behind. To make it a little easier, this quiz is multiple choice. The animals you must match to each of the samples are: bald eagle, gentoo penguin, wild boar, snow leopard, mullein moth caterpillars and brown long-eared bat. For the answers – as well as some amazing facts about these animals' faeces – turn the page.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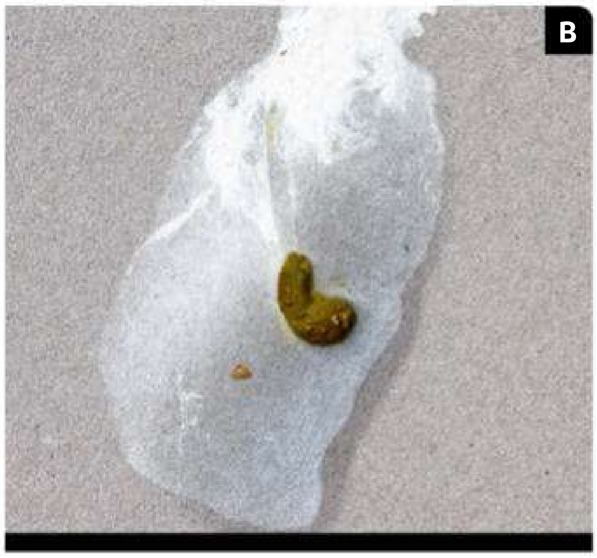
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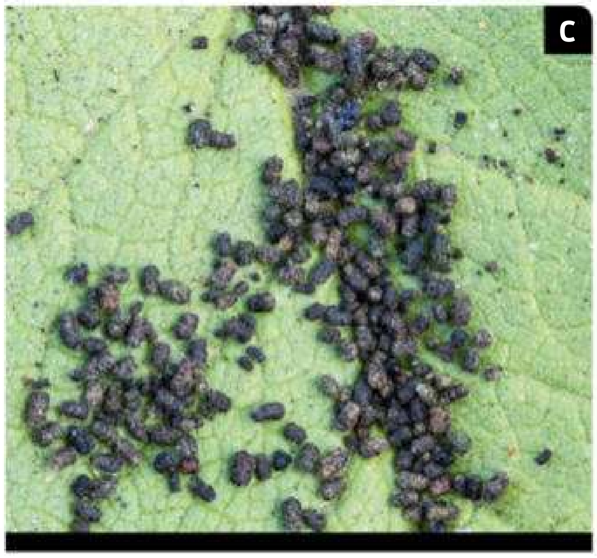
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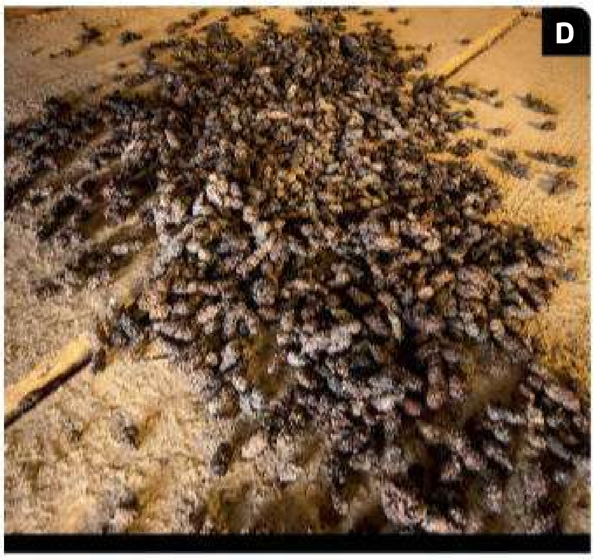
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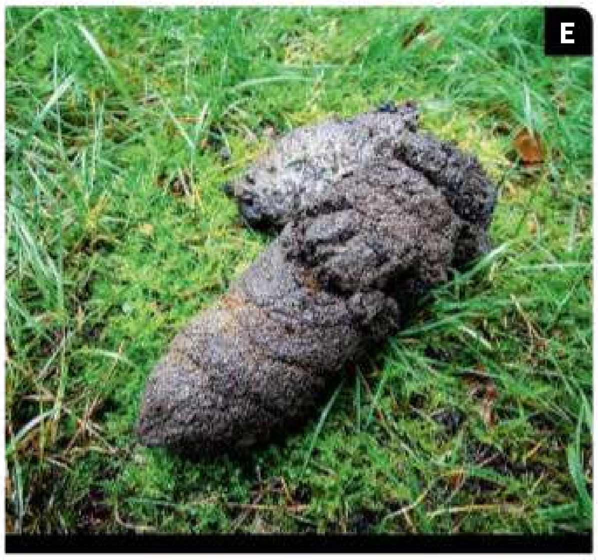
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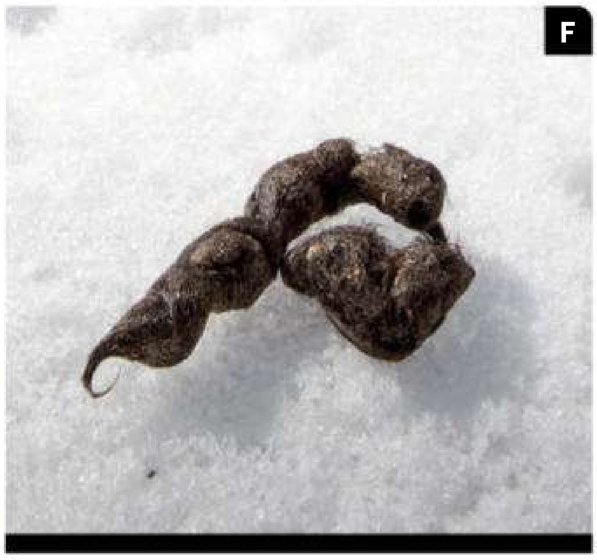
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ALL IMAGES BY CHRIS PACKHAM

GENTOO PENGUIN

A

This delightful dropping was left by the third largest species of penguin. Gentoo guano often comes in streaks because penguins create high pressures in their gut that shoot it a long distance. Researchers at Kochi University in Japan calculated that the pressure inside the rectum of a pooping penguin can reach 28 kilopascals – which is enough to propel their guano to a distance of 134 centimetres. That is like a human shooting their poo more than 3 metres.

In 2019, Bo Elberling at the University of Copenhagen in Denmark and his colleagues were studying penguin guano when they noticed they were beginning to get high. It turns out that penguin poop contains a large amount of nitrous oxide, otherwise known as laughing gas. That's because penguin diets contain a lot of krill and fish, both of which are rich in nitrogen.

BALD EAGLE

B

If you got this one right, it might have been because of the white colour many of us associate with bird poo. But bird poo is more complicated than many of us realise. Unlike most animals, which, crudely put, urinate and defecate through different holes, birds egest everything through one exit, the cloaca. They also convert their urine into concentrated uric acid to save water – this is the white, sticky stuff that gets onto cars. It is really closer to bird urine than faeces. For eagles, as for other birds, the solid waste is a separate thing, as seen in the photo. By the way, did you know that eagle excrement is often responsible for short-circuiting power lines? The birds use the towers that support power lines as lookout posts, and streaks of poo can provide a link between the power-carrying cables and the tower.

MULLEIN MOTH CATERPILLARS

C

These little pellets are the waste of caterpillars, known to the people who study such things as frass. The specific animal that did this business is the caterpillar of the mullein moth, which lives throughout much of Europe. It is useful to scientists, who count the frass and use it as a proxy for how much food will be available to birds each spring. It is an important matter to monitor, since climate change is throwing off the timing of peak caterpillar hatching and chick fledging, which need to be in synchrony for the chicks to thrive.

The waste of other caterpillars is also useful. For instance, one study from 2017 found that the Mediterranean flour moth's frass inhibits the growth of a broad spectrum of harmful bacteria. It could be that caterpillar excrement is where we will discover some of our next best antibiotics.

BROWN LONG-EARED BAT

D

Even for the trained naturalist, it can sometimes be tricky to tell the difference by eye between the guano of bats and droppings from rodents. That is easily solved if you pick up a pellet. Place it in the palm of your hand and drag it along with a finger. If it smears, it is likely to have been left by a mouse. If it crumbles to dust, then it is likely to be bat dung. All the UK's bat species are insectivorous, so their poo is mostly made of the exoskeletons of moths and suchlike, giving it a dry consistency.

You can also tell which species of bat did the droppings by looking at their distribution. If they are smeared up walls, that often indicates pipistrelles. If they have built up in large piles, that indicates you have the brown long-eared bat close by. Oh, and if you do ever pick up animal faeces, be sure to wash your hands thoroughly afterwards.

WILD BOAR

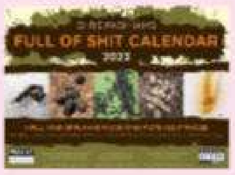
E

In 2014, enterprising researchers calculated the average daily defecation rate for wild boar. It came out as between 3.8 and 4.3 poos per day, which is a lot when multiplied by many animals. Wild boar faeces can contain some nasty pathogens, including an assortment of parasitic worms that can infect humans. With the population of wild boar booming, notably in the US, that brings danger. You might think you are safe as long as you don't touch the droppings. But in 2021, Anna McKee at the US Geological Survey and her colleagues analysed water from Congaree National Park in South Carolina, where people often do watersports. They looked for biological markers of excrement from humans, chickens, cows and swine – and found that poo from pigs was the most abundant kind. It is one reason why feral pigs are so problematic, along with the crops they destroy and traffic accidents they cause.

SNOW LEOPARD

F

Snow leopards are shy animals that inhabit the world's highest, most inhospitable terrain. These features make them famously hard to study. But they mark their territory with scent, often before evacuating their bowels – and their scat is easier to find than the cats themselves. In 2017, Madhu Chetri at the National Trust for Nature Conservation in Nepal retrieved more than 300 samples of this cat scat from the central Himalayas. Their analysis revealed that the samples had been left by 34 snow leopards. This showed the animals' population density was about one leopard per 100 square kilometres – lower than previous estimates, which had probably



This quiz is based on Chris Packham's Full of Shit Calendar 2023, which contains plenty more fascinating facts about faeces. For more details and to order yours, go to chrispackham.co.uk

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CHRISTMAS IS COMING

Find the perfect festive gift for someone special.
See website for December discount offers.

www.galaxyonglass.com

Puzzles
Try our cryptic crossword and festive puzzles p82

Quiz of the year
Can you remember all the biggest science news of 2022? p84

Puzzle and quiz answers
Find out how well you did p86

Feedback
Seasonal swings and Bing Crosby's white noise p88

Twisteddoodles for *New Scientist*
Picturing the lighter side of life p88

Citizen science

Partridge in a pear tree?

Join the Christmas Bird Count and contribute to conservation research this December and January, says **Layal Liverpool**

Layal Liverpool is a science journalist based in Berlin. She believes everyone can be a scientist, including you. @layallivs

What you need

Access to the National Audubon Society's website at audubon.org, or to eBird at ebird.org
A pair of binoculars for bird spotting

THREE French hens, two turtle doves and a partridge in a pear tree – the lyrics to a festive song, or perhaps an unlikely series of birding observations? You can find out this December and January by heading outside to birdwatch in the name of science.

If you live in North, Central or South America, you could participate in the US National Audubon Society's annual Christmas Bird Count, which runs from 14 December until 5 January. During this period, volunteers can join bird-counting groups and help to perform censuses of birds in pre-defined, 24-kilometre-diameter circles. You can use the map available on Audubon's website to search for a count circle near you, or use it as inspiration to start your own.

Information gathered through the Christmas Bird Count is made publicly available and contributes directly to conservation and ecology research. The survey was started in 1900 by US ornithologist Frank Chapman as a conservation-friendly alternative to the tradition back then for hunters to compete to kill birds at Christmas. Since that time, research informed by the yearly survey has helped to demonstrate how climate change and habitat loss are contributing to changes in the distributions of bird populations.

An analysis of Christmas Bird Count data collected across the US and Canada between 1969 and 2019 found that populations of 16 duck species had shifted northward during this time period as winters became warmer.

CAROLINE TROTTER/ALAMY

A study earlier this year analysed 90 years of Christmas Bird Count data from 119 count circles in the eastern US and found the winter ranges of all observed birds had altered in response to climate change. This effect was compounded by habitat loss, to which habitat-constrained birds such as waterfowl and grassland species are particularly vulnerable.

Identifying the overlapping effects of climate change and habitat loss on bird populations is important for informing conservation efforts. "Protecting birds from climate change in the future needs to go hand in hand with protecting healthy natural spaces that birds need right now," said Marshall Johnson, chief conservation officer for Audubon, in a statement commenting on the recent research findings.

The Christmas Bird Count isn't the only way to contribute to conservation research through birding. The Cornell Lab of Ornithology's eBird platform allows users to submit sightings year round from anywhere in the world. And if you live in the UK, you may wish to take part in the Big Garden Birdwatch, an annual survey organised by conservation charity the RSPB, taking place from 27 to 29 January 2023.

As for partridges (pictured), they are typically ground-dwelling birds – so you are unlikely to spot one in a pear (or any other) tree. ▮

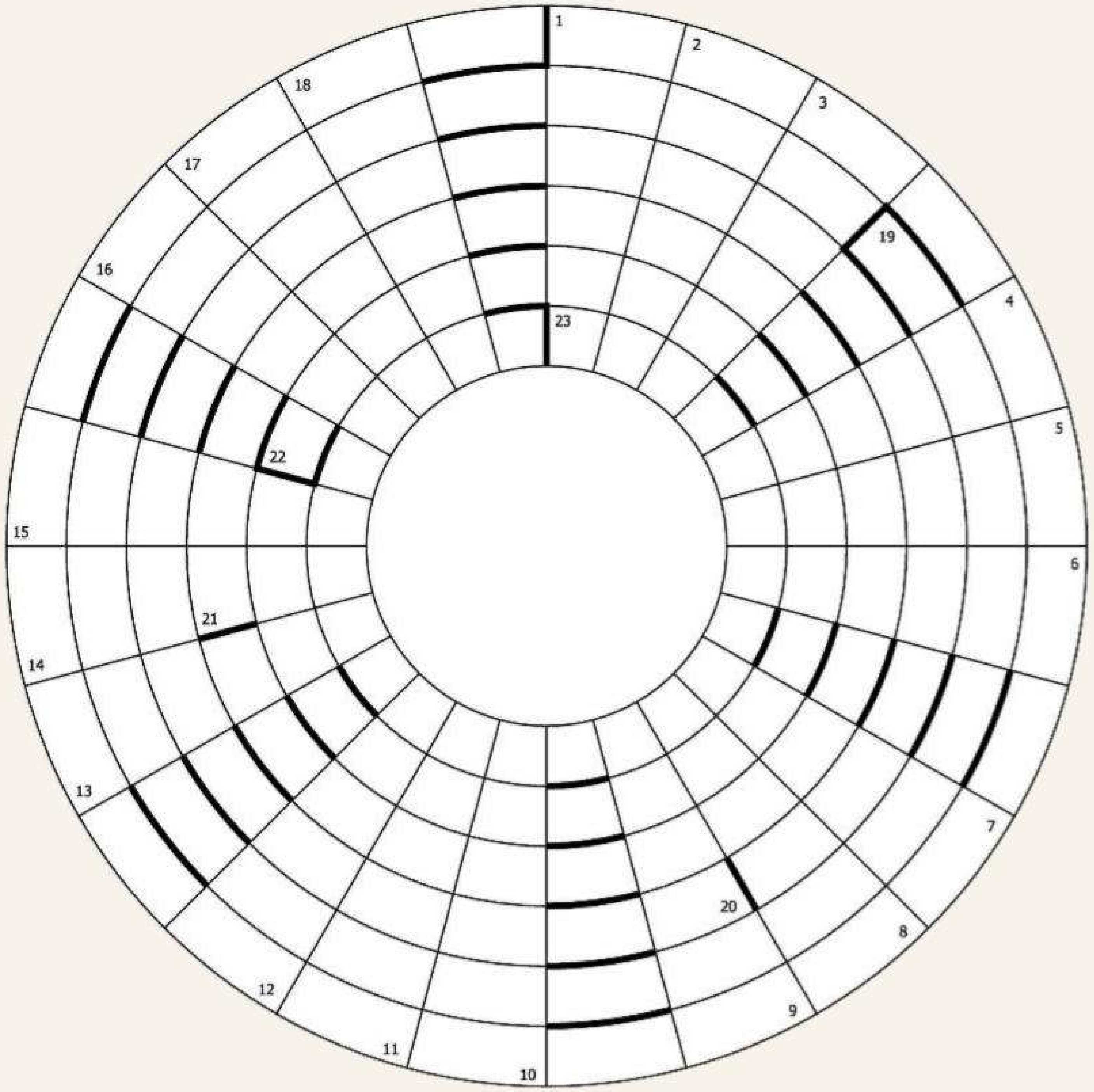
Citizen Science appears every four weeks. Share your citizen science adventures with us on Twitter and Instagram @newscientist, using the hashtag #NewScientistCitizenScience

Next issue

The science of cooking

These articles are posted each week at newscientist.com/maker

Cryptic crossword #99 *Set by Rasa*



Stumped

In this special cryptic, the lonely dendrochronologist's smartphone programming project is described by the answers to the two starred clues.

Annular (ring) entries start where indicated; clues are in order, proceeding clockwise. Once in each ring, the end of one entry and the beginning of the next will form a new word between five and eight letters long, to be placed in a single cell.

Each radial entry may be entered inwards or outwards; the solver determines which. Six of the radial entries are one letter too long for the grid. These excess letters, to be entered in the centre of the grid, spell a competing program that you probably shouldn't install on the same phone.

Our crosswords are now solvable online
newscientist.com/crosswords

Answers and the next quick crossword in the next issue

For a guide on how to solve New Scientist's cryptic crossword visit:
newscientist.com/cryptic

ANNULAR

1 Didn't keep silent wheel part (5)
Bear dwellings not quite tightly packed (4)
Rolled cubes down glacier, for instance (4)
Exchanging two letters, attract famous naturalist (6)
MD's Word files (4)
Lay out mail worn by page (5)
Tech company promo accompanies Nobel's content (5)
Ecuador broke ground, bounced back (6)

19 Book of maps lacks Turkey's capital, unfortunately (4)
Observed part of an act at an audition (4)
Change plunderer on the way back (6)
Regularly amp up software (3) *

20 Cocktail skirt shortened on both sides (3)
Arlo's out of the sun (5)
Make cold captain rise (5)
The Avengers co-star and Labour leader, interrupting my group, exhibit excitement (7)
500 leaves put under carpet (3)
Charge involves termination of their internet bully (5)

21 Metal popular at clubs after Ozzie's heart (4)
Even adjusted diet (4)
Most affluent patrons essentially twisted ethics (7)
Couple of nudists almost rip into fabric shelter for fuel? (8)
Copy a pirate's coat (3)
Avenge stranger abandoned by a desert (5)

22 Fine pale sepia veils from Kathmandu, maybe (8)
Painter's supply is able to preserve backing, error free (6)
Writes part 4 of series on retirement income (7)
Joy cracked toenail (7)

23 Newspaper features with, for example, nog ingredient (3,3)
Require massage, we hear (4)
Force deep groove, turning over sod (4)
Multicoloured horse raced around loop (4)
Cash drawer traps white suiting fabric (5)
Serious-looking punk showily drops fork (6)

RADIAL

1 Found a buyer for, um, alloy
2 Closely examines unusual tree sap (2 words)
3 Eccentric party beyond dam
4 Use mouthwash with half of garlic gel concoction
5 Dendrochronologist's work involving growth rings and IT wasted £1000 *
6 Opposite expressed via poetry?
7 Snuggles lessen hurt surrounding slight, finally
8 In America, quaintly called princess a source of illumination
9 Distressed kin returning best calligraphy accessory
10 Upon reflection, extend subscription around mid-April for physicist Heisenberg
11 Emphatic pronoun fits uninitiated North Pole helper
12 Mythical beast protects old fighter on horseback
13 Storybook pig playing viola captivates infants at first
14 Dish of stuffed dough recalled French lake district
15 Newton wears bisected first-aid device
16 Reverse jump disrupted by remote-controlled object wrapped in paper
17 Spooner's advice: travel on dangerous current
18 Soprano and I go into an Asian river

#198 Christmas candles

set by Paulo Ferro

Your turkey needs exactly 6 hours to slow roast. Alas, you have no timer, just three candles: one that burns in 3 hours, one that burns in 4 hours and another that burns in 5 hours.

How can you measure 6 hours using these candles, putting the roast in the oven at the same time as you light the first candle?

SHUTTERSTOCK/TASSEL78

#199 Sneaking a peek

set by Brian Hobbs

Dear Santa,

I can explain. We weren't planning to peek at the gifts Aunt Emily brought us, but the receipt was sticking out of one of the bags and Joe accidentally saw it and accidentally told us, so then we knew she got us all lightsabers, two green and three blue. Edmund wants a blue one and I want green. Timothy said it wouldn't really be cheating if we only peeked at the gift of the sibling younger than us, but I said that isn't fair because I'm youngest, so we agreed to look at the gifts of both the siblings younger and older than us, which means I only looked at one and it was only a tiny peek.

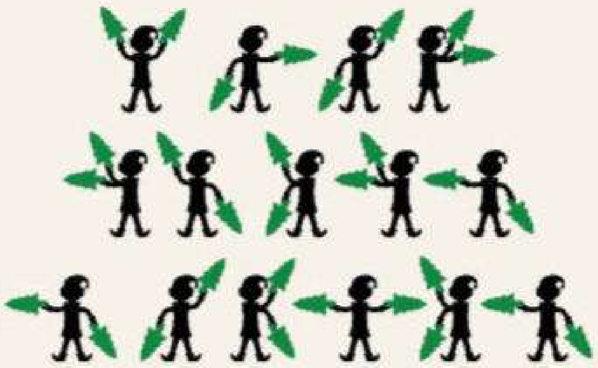
After that, Georgia asked if anyone knew what they themselves got, and we all said no, except then she smiled and said that if no one else knew, then she did know. I guess I'll just have to wait to know what colour mine is. I hope you can still bring me presents and please take the lightsabers off the list I sent you.

Love,
Sophie

What colour was Sophie's lightsaber?

#200 A picture of elf

set by Katie Steckles



'Twas just a few days before Christmas. Santa was out for a revitalising walk on the hills around his workshop with his sleep-deprived elf companion Bubby, when he spied a group of other elves moving around on the next hill. "Ah," he surmised. "They're using their special secret elf communication system that only elves can understand, elf-maphore." The system involves holding two trees in specified positions to represent a letter of the alphabet.

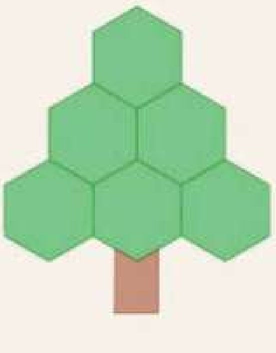
As they watched, three separate groups of elves ran up to the top of the hill and each group spelled out a different word. "What does the message say?" Santa asked. Bubby flipped her elf hat over to the right, as elves always do when using the language, and squinted her tired eyes at the elves on the far away hill, watching them repeat the message. "Well, it appears to say PSTA HERHL LTNORL. But that can't be right!"

What is the message?

#201 A prime Christmas tree

set by Paulo Ferro

Your challenge is to fill each hexagon in the Christmas tree with a different prime number. Each side of the triangle the tree makes must add to the same sum and each line's total should be as small as possible. Note that, by convention, 1 isn't a prime number.



Answers to the festive puzzles, plus the solutions to 10 December's puzzle and crossword, are on page 86

Put yourself to the test

The past 12 months have seen the invasion of Ukraine, the spread of the omicron coronavirus variant, an energy crisis and heatwaves around the world. But there were also lots of weird and wonderful science stories. **Bethan Ackerley** is here to see what you recall

1 There have been some truly gargantuan scientific discoveries this year. But which of the following didn't we report on in 2022?
A The largest fish colony yet found
B The largest quantum computer yet made
C The largest red dwarf yet detected
D The largest species of bacteria yet discovered

2 Going to the other extreme, in January, researchers informed us of the discovery of a creature so tiny it could fit into a grain of sand. This is the smallest species of which kind of animal?
A Jellyfish
B Land snail
C Clam
D Ringworm

3 Speaking of superlatives, in February, the Australian raspy cricket was found to be superior among 650 insect species in what way?
A It had the strongest bite
B It had the longest legs
C It jumped the furthest
D It had the loudest chirp

4 In August, we looked at five numbers that could reveal the history of the universe, including the doppelgangion, the chance of there being another person exactly like you. What is this number?
A 10 to the power 80
B 10 to the power 10 to the power 68
C 10 to the power 10 to the power 100
D 10 to the power 10 to the power 10 to the power 475

5 Lycopene, the chemical that gives tomatoes their red colour, was found to have what other special ability in May?
A It makes solar panels more efficient
B It is antiseptic
C It deters mosquitoes
D It is an aphrodisiac for flies

6 What was the newly identified *Iberospinus natarioi* dinosaur constantly losing, as we learned in February?
A Its feathers
B Its teeth
C Its claws
D Its temper

7 Sticking with dinosaurs, throughout 2022 we have reported on the controversial claim that what we have long known as *Tyrannosaurus rex* (illustrated below) was in fact three separate species. Alongside *T. rex*, what are the other two proposed species?
A *T. domesticus* and *T. simplex*
B *T. dynastes* and *T. regalis*
C *T. acanthus* and *T. laevis*
D *T. imperator* and *T. regina*

MARK TURNER/ALAMY

8 In November, the oldest readable sentence written using the first alphabet was revealed (pictured far right). What did it discuss?
A Vegetables
B Head lice
C Gossip
D Latrines

9 How did the European common toad surprise biologists, as reported in March?
A It uses tools
B It is found in South America
C It climbs trees
D It changes colour

10 In October, we carried a story about certain acids in our body odour that make humans more appealing to which creatures?
A Mosquitoes
B Bears
C Rhinos
D Other humans

11 What shape of city gets the most rain, as we learned in May?
A Circular
B Triangular
C Square
D Rectangular

12 In October, physicists announced they had made the most precise measurement of a particle ever. What type of particle was involved?
A A W boson
B A top quark
C An electron
D A gluon

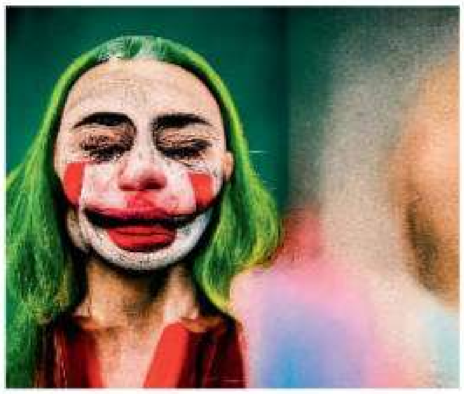
SHUTTERSTOCK/BBA PHOTOGRAPHY

13 In March, we interviewed slug researcher Rory Mc Donnell, who has been researching the best ways to control invasive slugs. Which bait turned out to be most effective in his team's tests?
A Guinness
B Cat food
C Bread dough
D Lettuce

14 I hope you aren't eating during this next question. In May, we learned that members of a certain marine species identify their friends by tasting their urine. Which animal was this?
A Leopard seal
B Bottlenose dolphin
C Humpback whale
D Hammerhead shark

15 Urinary matters were clearly a hot topic in May: that month, we also learned that pregnant mice release a chemical in their urine that deters males. What does it smell of?
A Bananas

HOU YU/CHINA NEWS SERVICE VIA GETTY IMAGES



SUPERCOMPOSITE/TWITTER

DENYS KOVTUN/ALAMY

> "The oldest readable sentence written using the first alphabet was revealed in November"

DAFNA GAZIT/ISRAEL ANTIQUITIES AUTHORITY
GAP PHOTOS/TIM GAINEY

B Cheddar
C Sardines
D Aniseed

16 Let's raise the tone a little, shall we? In July, China launched the second module (pictured above) of its Tiangong space station. Its name, Wentian, translates to what?
A Lady of the Skies
B Salute
C Dreamer
D Quest for the Heavens

17 Keeping our eyes skyward, in March, NASA's Perseverance rover measured the speed of sound on Mars for the first time. How fast is it?
A Around 240 metres per second
B Around 340 metres per second
C Around 440 metres per second
D Around 540 metres per second

18 In April, we brought you news that the untimely demise of a *Triceratops* discovered in 2014 seems to have been caused by a stab wound to the head. But what has this fossil specimen been nicknamed by researchers?
A Gentle Ken
B Big John
C Mavis
D Timmy T

19 In October, we revealed that a US high school student named Indeever Madireddy sequenced the genome of his pet, the first time for the species. What was the animal?
A Calvin the freshwater angelfish
B Aidan the leopard gecko
C Victor the chinchilla
D Howie the axolotl

20 A *New Scientist* story published in May helped save a research lab, the funding of which had been cut. What does it study?
A Irritable bowel syndrome
B Seaweed
C Cloud formation
D Corvid cognition

21 In August, we learned that numbers of a much-beleaguered species had grown 10-fold since 2015. Which animal was on the up?
A Vaquitas
B Javan rhinos
C Saiga antelope
D Pangolins

22 We saw how artificial intelligence is untangling the mystery of knots in July. How many distinct knots has mathematician Benjamin Burton identified?
A More than 100 million
B More than 250 million
C More than 350 million
D More than 700 million

23 AI image generators exploded in popularity in 2022. But what nickname was given to a sinister woman (pictured above) who kept appearing in the images, as we reported in September?
A Crungus
B Loab
C Trullbus
D Mavise

24 In November, new prefixes for the world's largest and smallest numbers were agreed at the General Conference on Weights and Measures. Which of these prefixes wasn't approved?
A Ronna
B Quetta
C Ronto
D Quessa

25 Let's finish on a high. In April, we revealed that the world's highest living mammals are found on a volcano in the Andes and are members of which species?
A Leaf-eared mice (*Phyllotis vaccarum*)
B Vicuña (*Lama vicugna*)
C Domestic yaks (*Bos grunniens*)
D Mountain goats (*Oreamnos americanus*)

Answers on the next page

Quiz of the year
Answers

1 C – The largest red dwarf yet detected
2 B – Land snail
3 A – It had the strongest bite
4 B – 10 to the power 10 to the power 68
5 A – It makes solar panels more efficient
6 B – Its teeth
7 D – *T. imperator* and *T. regina*
8 B – Head lice
9 C – It climbs trees
10 A – Mosquitoes
11 A – Circular
12 C – An electron
13 C – Bread dough
14 B – Bottlenose dolphin
15 A – Bananas
16 D – Quest for the Heavens
17 A – Around 240 metres per second
18 B – Big John
19 A – Calvin the freshwater angelfish
20 D – Corvid cognition
21 C – Saiga antelope
22 C – More than 350 million
23 B – Loab
24 D – Quessa
25 A – Leaf-eared mice (*Phyllotis vaccarum*)

How did you do?

18-25 – Is that a stack of *New Scientists* we see beside you? Bravo! You clearly know your sciencey stuff.

12-17 – The unmistakable whiff of knowledge is emanating from you. Congratulations!

6-11 – Hmm. Feels like a heady combination of luck and educated guesses. Still, it is the taking part that counts, so well done.

0-5 – Oops. Even guessing every time should have delivered six points, on average. If you don't already have one, try a *New Scientist* subscription in 2023!

#198 Christmas candles
Solution

Here is one way. Light all three candles. When the 3-hour candle burns out, blow out the 4-hour candle. When the 5-hour candle burns out, relight the 4-hour candle for its final hour.

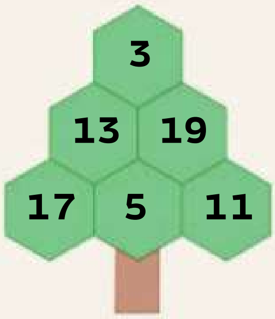
#199 Sneaking a peak
Solution

Sophie got a green lightsaber. The only way one of the children could know what colour they had after looking at two gifts is if they saw two green lightsabers, meaning the others would have to be blue. Since no one knows initially, the green ones can't be in the gifts of both the first and third children, or the second and fourth or the third and fifth. The only child who would be able to use this information to find out what they had is the third child and only if they saw two blue lightsabers. They would know they didn't have green because then the first or fifth child would also have green and the second or fourth child would have seen two greens. So she must have blue, leaving the oldest and youngest children with the green lightsabers.

#200 A picture of elf
Solution

The elf hats are tipped to the right, which means we must be viewing them from behind. The view from the front, showing the true message, will be a reflection of each word we can currently see. For example, the last signal in the first line will be the first letter of the message, but reflected left-to-right; the mirror image of this signal occurs elsewhere in the message, and according to the elf's initial translation, gives an H. The whole message reads HELP SANTA SNORES.

#201 A prime Christmas tree
Solution

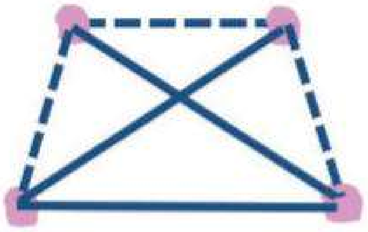


Cryptic crossword #98
(set on 10 December)
Answers

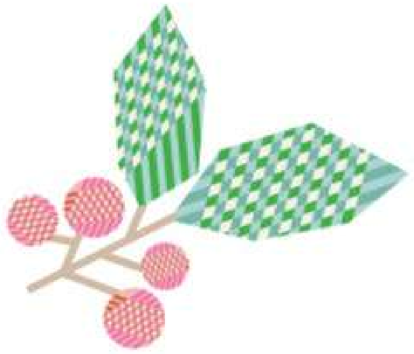
ACROSS 1 Hadal, **4** Bizarre, **8** Lily pad, **9** Niche, **10** Gladioli, **11** Soot, **13** Neaten, **15** Yawned, **18** Sire, **19** Headache, **22** Umbra, **23** Bromine, **24** Gosling, **25** Dwelt

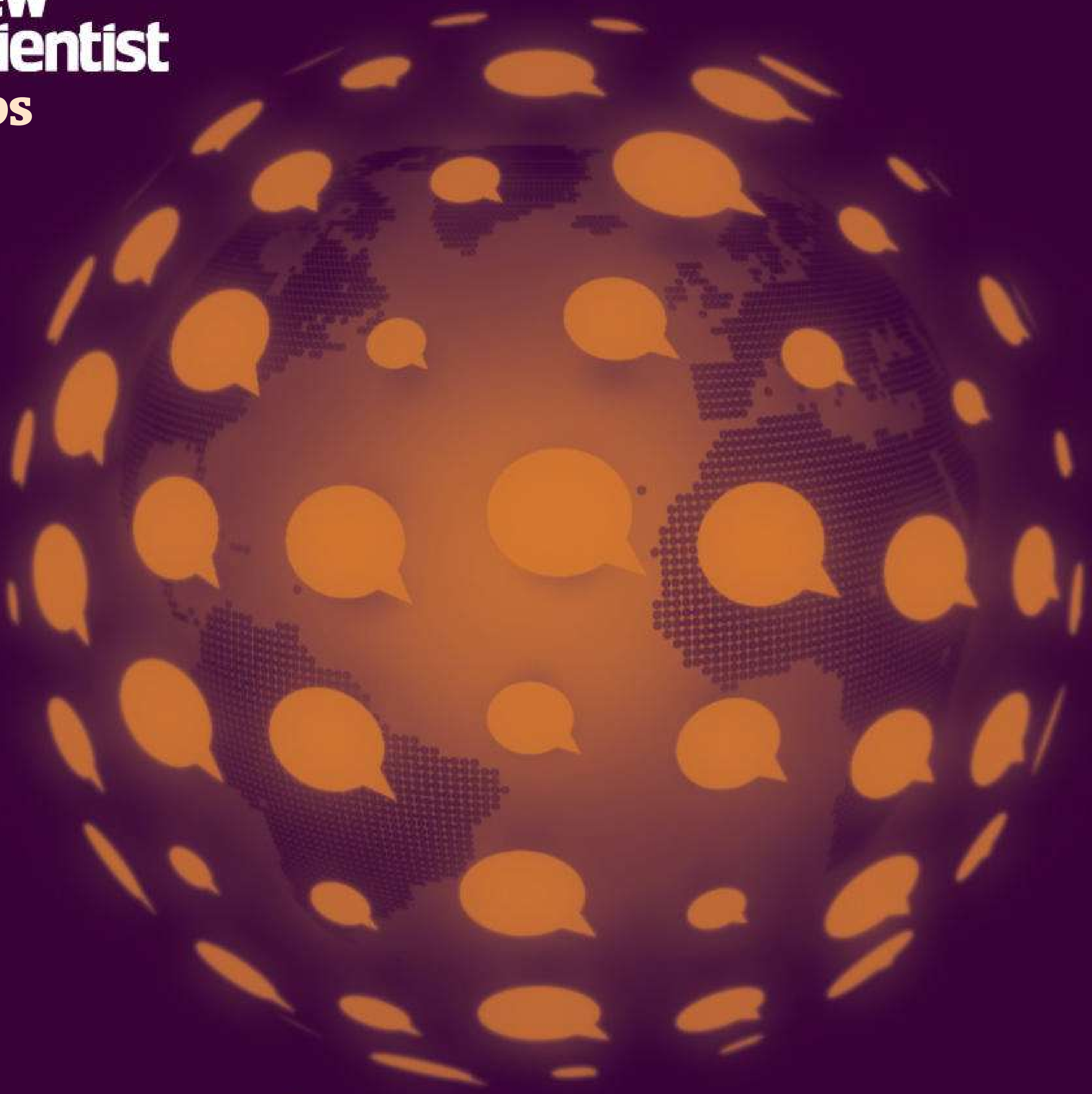
DOWN 1 Halogen, **2** Delta, **3** Lopsided, **4** Bodily, **5** Zone, **6** Raccoon, **7** Eject, **12** Hardwood, **14** Aerobes, **16** Due west, **17** Tea bag, **18** Stung, **20** Chive, **21** Taxi

#197 Marshmallow test
(set on 10 December)
Solution



The solid lines are the full-length cocktail sticks, the dotted lines are the shortened sticks. Two of the sticks cross each other, but the marshmallows are chubby enough that they can still all sit on the table top when this happens.





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newscientist.com/salarysurvey

May your daze be merry

A recent study builds on more than half a century of experiments to see whether people think they hear Bing Crosby crooning *White Christmas*.

Crosby's recording of the song, released in 1942, became enduringly popular. In the 1960s, Theodore Xenophon Barber at the Medfield Foundation in Massachusetts and his colleagues began using *White Christmas* – and also not using it – as an experimental probe. Volunteers were told to listen carefully, then to indicate whether they heard a song playing. There was no song to hear, just ambient noise or, in some experiments, generated white noise. In virtually every test, lots of people said they heard, or thought they may have heard, *White Christmas*.

One approach was to hypnotise each test subject before the listen-to-this session began. A Barber paper in 1964 sketched the impressiveness of the hypnosis protocol: "The subject was asked to fixate on a light blinking in synchrony with the sound of a metronome and was given a standard hypnotic induction procedure adapted from the induction procedures of Friedlander and Sarbin, Marcuse, and Weitzenhoffer and Hilgard."

The recent study, by Csilla Ágoston at Eötvös Loránd University in Hungary and her colleagues, used *White Christmas* to "explore the effects of acute caffeine intake and acute stress on perceptual distortions". It builds on an earlier Australian study that warned of the danger – of hearing an imaginary Bing Crosby, and perhaps of other hallucinations – when caffeine is added to a stressful life. The new study suggests that the stress is more potent than the caffeine in bringing on *White Christmas*.

Twisteddoodles *for New Scientist*

DEAR SANTA,
COULD I HAVE SOME FUNDING FOR MY RESEARCH?
URGH. THEY FORGOT THE GANTT CHART
@twisteddoodles

Got a story for Feedback?

Send it to feedback@newscientist.com or New Scientist, Northcliffe House, 2 Derry Street, London W8 5TT
Consideration of items sent in the post will be delayed

Seasonal upswing

Do seasonal holidays bring a predictable rise in the total number of alive-and-kicking humans? Research suggests that, firstly, the answer is predictably jumbled, and, secondly, it is likely to be marred by manipulations and errors in birth records.

A report called "Are the birthdates of our ancestors real? Date of birth misregistration in twentieth-century Poland" meanders with dry glee through some of the manipulated mess. This flavour of numerical high jinks, it points out, isn't unique to Poland.

Another study called "Holiday, just one day out of life: birth timing and postnatal outcomes" concentrates on the input, rather than the output, phase of the (re)production cycle. It analyses "sexual activity data collected from over 500,000 individuals".

Two patterns become especially clear. The first is general: "For all locations, New Year had the highest magnitude increase in sexual activity. This was comparable to the increase in sexual activity measured in Brazil during Carnival and Valentine's Day in the US and UK. Brazil was the country in which sexual activity was consistently higher around holidays."

The second pattern is more specific: "One pattern consistent among countries was decreased sexual activity in the three days before Christmas, which was followed by elevated sexual activity on Christmas and the three days after."

This information may be stimulating, but the researchers confess disappointment about what it can explain. There is a mismatch, they write, between the aggregate data-in and infant-out numbers. "Seasonal sexual activity alone," they explain, "would generate birth peaks in each country that do not match the peaks observed in the time series of births."

A study published in 1999 exposes one aspect of that statistical mystery by comparing two questions. When did the birth officially happen? And when did the child actually appear? The study is called "Taxes and the timing of births".

Seasonal downswing

Do seasonal holidays bring a predictable *drop* in the total number of alive-and-kicking humans (or, to phrase it more strenuously, a rise in the number who kick the bucket)? Research suggests that here, too, the answer is predictably jumbled and manipulation of the deaths records not only occurs, but sometimes happens to save oodles of money.

Complexities abound. For example, there is the holiday gift conundrum, as explored in a new study in *The Journal of Heart and Lung Transplantation* called "Heart transplant offers are less likely to be accepted on weekends, holidays, and conferences". Other studies poke at the deadliness of particular holidays, such as "The spring festival is associated with increased mortality risk in China" and "Mortality spike at New Year but not Christmas in north east England".

Inevitably, money croons a deathly tune. A 2003 paper nods to the birth-and-taxes issue noted above in accounting for what happens at the end of life. "Dying to save taxes: evidence from estate-tax returns on the death elasticity" says: "We investigate the temporal pattern of deaths around the time of changes in the estate-tax system periods when living longer, or dying sooner, could significantly affect estate-tax liability. We find some evidence that there is a small death elasticity, although we cannot rule out that what we have uncovered is ex post doctoring of the reported date of death."

And now, pursued by a barely heard Bing Crosby, onward, fellow Feedbackians, to 2023! ▮

Marc Abrahams

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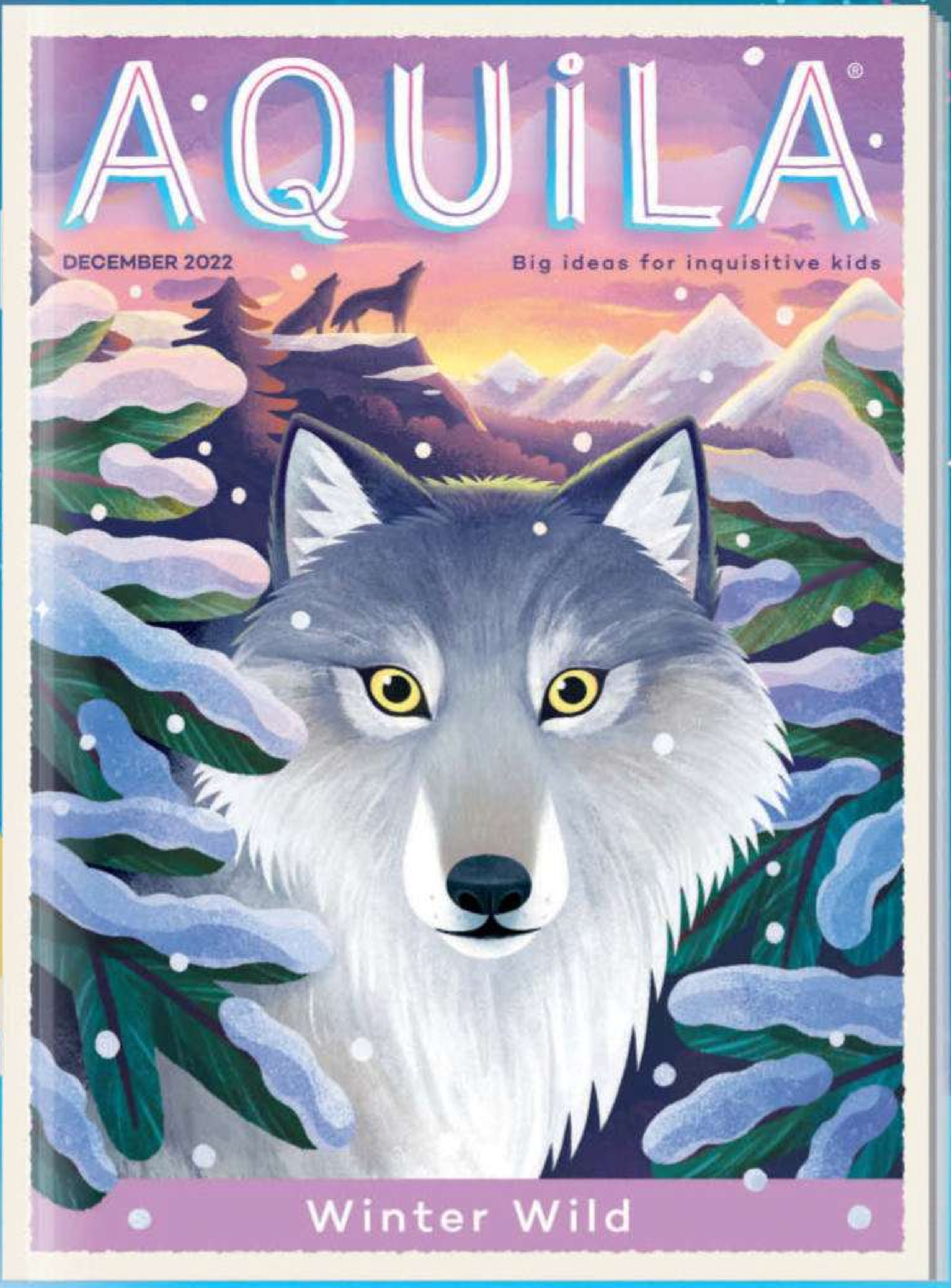

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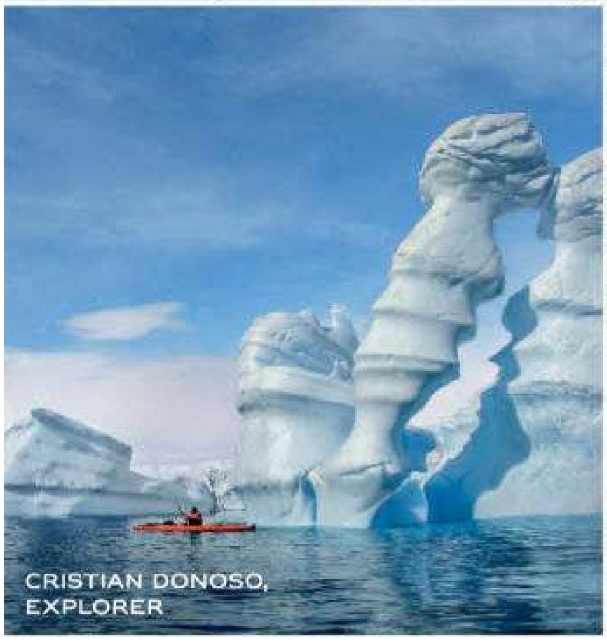
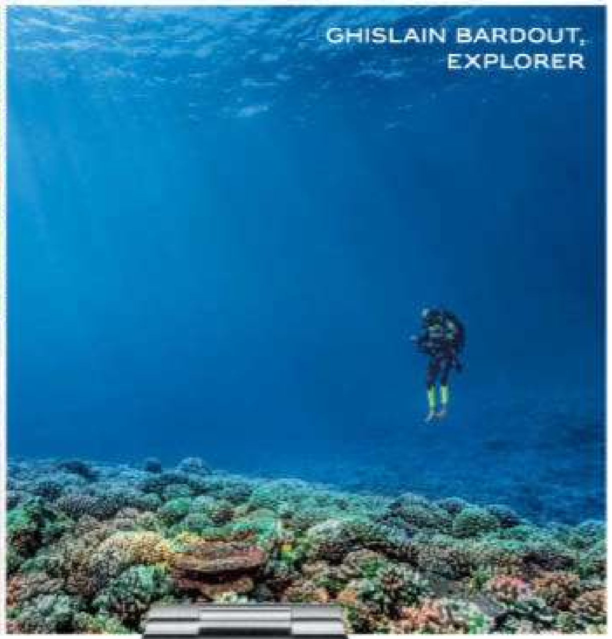


CRISTIAN DONOSO, EXPLORER

TOPHER WHITE, CONSERVATION TECHNOLOGIST

FRANCESCO SAURO, EXPLORER



GHISLAIN BARDOUT, EXPLORER

WHAT DO THEY SEEK?

Explorers, adventurers, scientists. Men and women who always broadened the horizons, for all humankind to share. Rolex was at their side when they reached the deepest point in the oceans, the highest summits of the Earth, the deepest jungles and both poles. But now that we know, more than ever, that our world has its limits, why do they continue to venture out there, again and again? Certainly not for kudos, accolades, or an ephemeral record. What they truly seek is to understand more intimately how complex and delicate our planet is, to document its change and how together, we can affect it for the better. So as long as they need it, we will be at their side. Because today, the real discovery is not so much about finding new lands. It's about looking with new eyes at the marvels of our planet, rekindling our sense of wonder, and acting to preserve our pale blue dot in the universe… **Doing our very best for a Perpetual Planet.**

#Perpetual

OYSTER PERPETUAL ROLEX DEEPSEA

ROLEX